

**Economics of Dockage Removal in Barley: Background,
Cleaning Costs, Handling, and Merchandising Practices**

By

William W. Wilson, Daniel J. Scherping,
David W. Cobia, and D. Demcey Johnson

Department of Agricultural Economics • Agricultural Experiment Station
North Dakota State University • Fargo, ND 58105-5636

ACKNOWLEDGMENT

This research was financed by the Federal Grain Inspection Service (FGIS) through a Cooperative Agreement (#58-3AEK-0-800094) between the Economic Research Service (ERS) of the USDA and the North Dakota Agricultural Experiment Station. The authors acknowledge the following individuals for providing input, data, and direction for the analysis: Brad Anderson, Feed Grain Analyst, ASCS; Alan Slater, Busch Agricultural Resources, Inc.; John Mittleider, North Dakota Barley Council; Les Backer, Department of Agricultural Engineering, North Dakota State University; and Mark Ash, USDA/ERS, Washington, DC. Frank Dooley and Charlene Lucken, Department of Agricultural Economics, North Dakota State University, are acknowledged for their comments and assistance.

We are grateful to the country elevator managers and representatives of grain cleaner manufacturers who provided much of the data. Remaining errors and omissions are those of the authors.

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Highlights

In the U.S. marketing system, dockage in barley is a nongrade-determining factor. Consequently, the dockage level is a contract term that is subject to negotiation in individual contracts between buyers and sellers. Incentives to remove dockage depend on the configuration of grade limits and intergrade price differentials. However, concern has increased about whether the U.S. system is competitive and whether changes should be legislated to improve grain quality in grade standards of most grains. The purpose of this study was to analyze why and where barley is cleaned, cleaning costs, merchandising practices, and impacts of different policies regulating dockage removal.

Barley is somewhat unique in the grain industry because of its distinct classes and varieties used throughout the marketing system to indicate quality. Barley is classified by varieties, either feed or malting. In addition, barley is classified as 2-rowed and 6-rowed, depending on the type of variety. The American Malting Barley Association (AMBA) recommends barley varieties for specific states for malting purposes, and the recommendations are adopted in the grading system.

Canadian grade standards for barley differ from those in the United States in several respects. Procedures for measuring and reporting dockage in the two countries also differ. Results in this study indicate that if the Canada Grain Commission and the U.S. Federal Grain Inspection Service report the same dockage level following their own official testing procedures, Canada's barley would have about 0.45% less dockage than would U.S. barley.

Dockage is removed in the U.S. marketing system in response to explicit or implicit commercial incentives. Although the amount of dockage removed within the domestic marketing system has increased, dockage in export shipments is substantially greater. This varies across importing countries and has not decreased as it has in the domestic marketing system.

Important conclusions from the cost analysis in this study are

1. Barley loss is the most important variable cost associated with cleaning. Barley loss accounts for up to 86% to 89% of the total cost of cleaning. Documentation on the extent of barley loss when cleaning to lower dockage levels is limited.
2. Cleaning costs were estimated at 4.3¢/bu and 7.9¢/bu assuming an initial dockage level of 2.5% and ending dockage level of 0.8% and 0.2%, respectively.
3. The value of barley loss and cleaner utilization affects cleaning costs.

A budget analysis of cleaning decisions was conducted. Results illustrate impacts of variability in important factors on the net benefit of cleaning (or profit from a decision-maker perspective). These factors include initial and ending dockage levels, the value of

barley loss, revenues from sales of screenings, and transport savings. Changes in any of these impact cleaning profitability.

A detailed analysis was conducted to aggregate the costs and benefits of alternative legislated levels of dockage in barley. Under base-case assumptions, the net cost to the industry when cleaning to 1% ending dockage would be \$3.9 million and when cleaning to 0.2% ending dockage \$7.2 million. The net costs are largest in Idaho because of the high barley price, which implies a higher value of barley lost in the cleaning process. Sensitivity analysis demonstrates that lower initial dockage levels raise the net cleaning cost and higher screening values and transport costs reduce net cleaning costs.

Economics of Dockage Removal in Barley: Background, Cleaning Costs, Handling, and Merchandising Practices

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Introduction

As competition among suppliers and specification demands of buyers increase, grain quality has received more attention. Dockage and cleanliness have received most of the attention in the United States. Buyer requirements are met through contract specifications, and dockage is a nongrade-determining factor. Unlike other quality characteristics, dockage can be removed and levels lowered through cleaning. In some producing regions, this is a common practice.

Policies to ensure that dockage levels in U.S. grains are competitive with those of major competing countries have become of growing interest. Numerous approaches could be implemented to reduce dockage levels in U.S. grains, each having a different impact on the marketing system and competitiveness of U.S. grains in the international markets. The 1990 Farm Bill includes a provision to study benefits and costs of cleaning grains before the Federal Grain Inspection Service (FGIS) makes any changes in the grade standards with respect to dockage. The Economic Research Service (ERS) in a cooperative agreement with North Dakota State University (NDSU) initiated studies on the impact of incorporating dockage into grade standards for hard red spring wheat, white wheat, durum, and barley.¹

This study is the first of a two-part series of the NDSU/ERS study on economic impacts of regulating dockage removal from barley.² The report analyzes why and where barley is cleaned, the cleaning costs at different locations in the marketing system, merchandising practices, and impacts of different policies regulating dockage removal. This report summarizes NDSU work on the ERS study. A more comprehensive version which includes detailed data on the surveys (published as a technical report) is available from the authors.³

*Professor, former research assistant, professor, and assistant professor, respectively, Department of Agricultural Economics, North Dakota State University, Fargo.

¹A related paper was prepared by the Standards and Procedure Branch of FGIS, USDA(D) in its five-year review of barley standards titled *Discussion Paper on the U.S. Standards for Barley*. The Standards and Procedure Branch is required by law to review grain standards every five years. The purpose of that paper was to provide a starting point to discuss areas of interest to all participants in the barley industry.

²A companion paper by Johnson develops a model that illustrates cleaning and blending decisions of commercial handlers.

³In addition, a forthcoming study on the North American barley and malt market by Johnson and Wilson analyzes impacts of agricultural and trade policies and the impacts of quality on competition in the barley and malt sector.

There are six major sections. First, background on production and use are described. Second, quality characteristics are described, and dockage is defined. Quality characteristics and dockage levels at various points in the marketing channel are presented and compared with the Canadian system. Third, handling and merchandising practices are examined, including results from two comprehensive surveys. Fourth, technologies are discussed, and economic-engineering costs of barley cleaning are presented. Components of cleaning costs are examined, and the impact of critical variables on costs are analyzed. Fifth, a budget analysis of grain handlers' cleaning decisions is presented to show impacts of selected cleaning factors. Sixth, an analysis of aggregate economic impacts that certain policies would have on the grain marketing systems is presented.

United States Barley Supplies

Yearly production and carryover stocks determine barley supplies in the United States. Although the Midwest and Western United States are well suited for barley production, government farm programs also influence barley production and regions.

Barley was introduced into the United States primarily in two areas. Early settlers of the Atlantic seaboard brought barley from their homelands in the 16th Century. Barley introduced on the eastern coast accounts for most of the history and development of barley in the United States. Spanish missionaries also introduced barley in the Southwest in the 17th Century (Wiebe).

Early settlers found barley growing conditions along the east coast favorable. However, barley was produced in these areas because of brewery demands. More favorable growing conditions were found in the New England colonies. Westward movement of barley production coincided with the development of the transportation system, facilitating longer distance movements of barley from production to demand regions. Gradually, higher valued crops displaced barley in traditional growing regions (Wiebe).

Barley production is concentrated in the Midwest and western states (Figure 1). Barley generally is grown in regions that are not suited for row crops competing largely against wheat acreage. Acres planted to barley vary from year to year; however, 10 states (California, Colorado, Idaho, Minnesota, Montana, North Dakota, Oregon, South Dakota, Washington, and Wyoming) account for about 90% of the acres planted since 1980 (Figure 2).

Planted acres have declined since 1960, mainly in California and states other than the 10 major barley-producing states. Notable declines in the area planted have occurred since 1985 because of combined effects of reduced loan rates, the Acreage Reduction Program (ARP), and the Conservation Reserve Program (CRP). Because of the economics of farm program participation and the fact that these programs are particularly effective in the principal producing states, most of the decline since 1985 has been from larger producing states. However, production has increased slightly since 1960 because of increased yields (Figures 3 and 4). Major droughts in 1974 and 1988 greatly reduced barley yields and production.

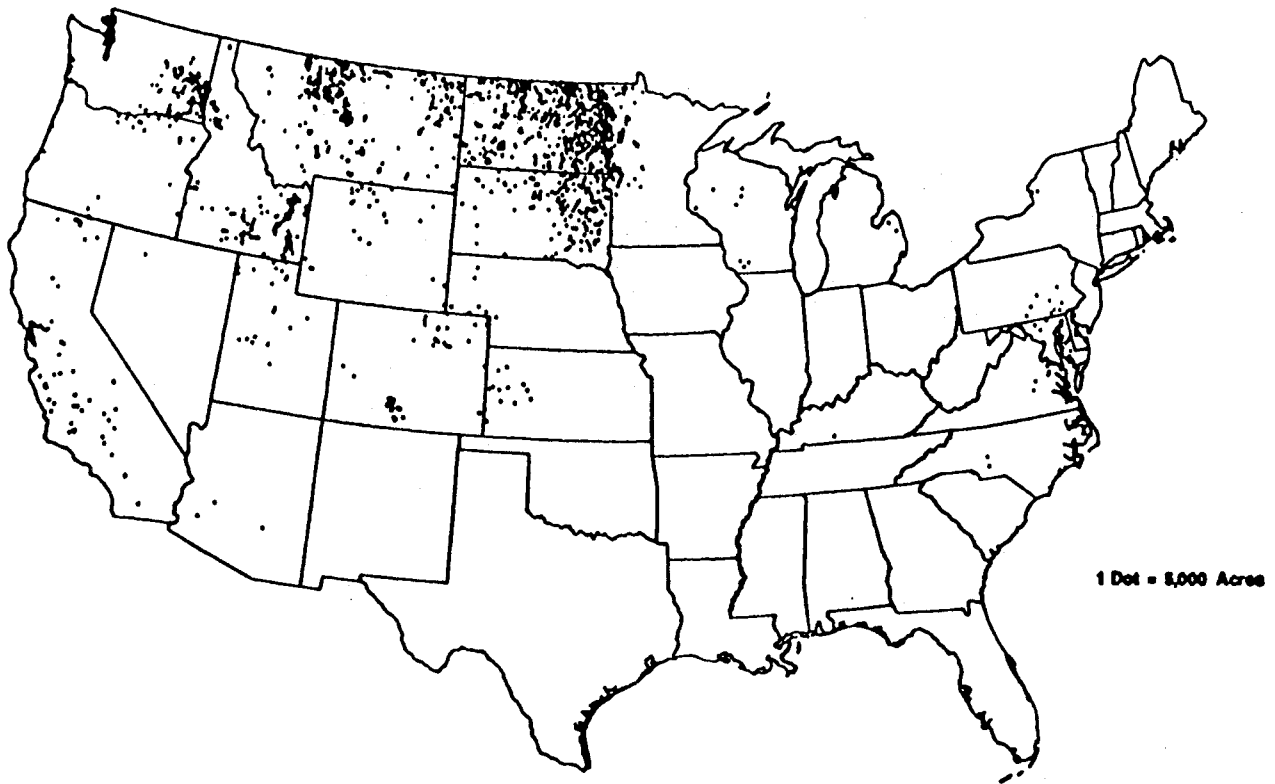


Figure 1. 1987 Barley Acreage for Grain.

Source: U.S. Department of Commerce.

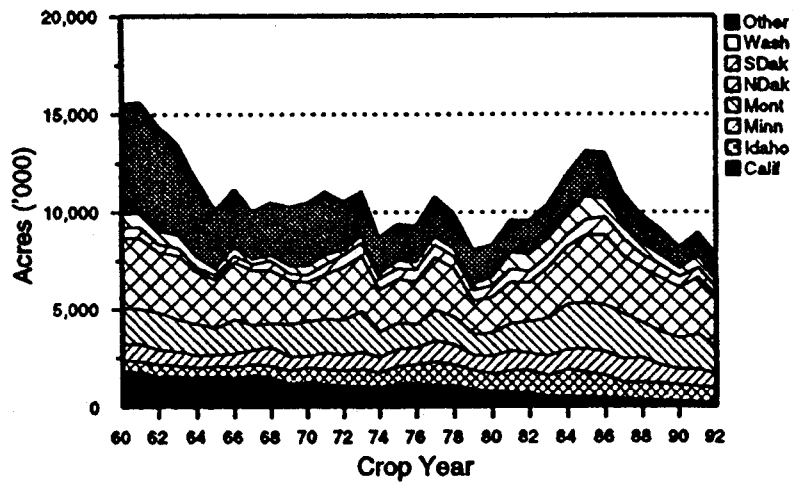


Figure 2. U.S. Acres Planted to Barley.

Source: USDA(F).

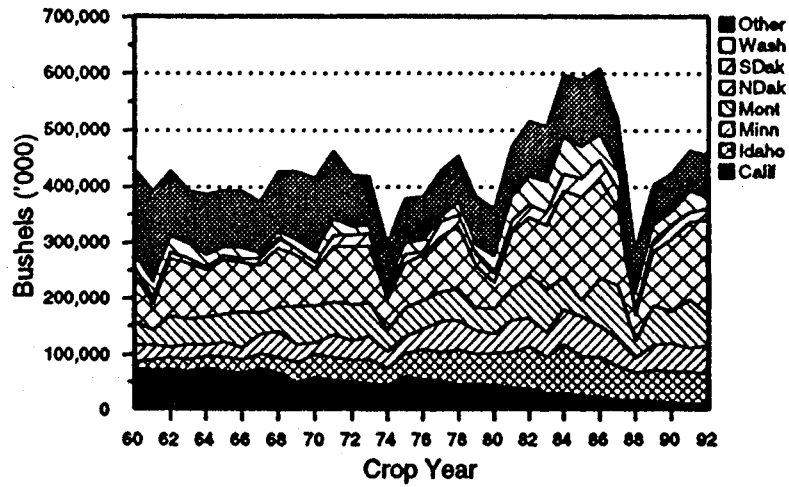


Figure 3. U.S. Barley Production.

Source: USDA(F).

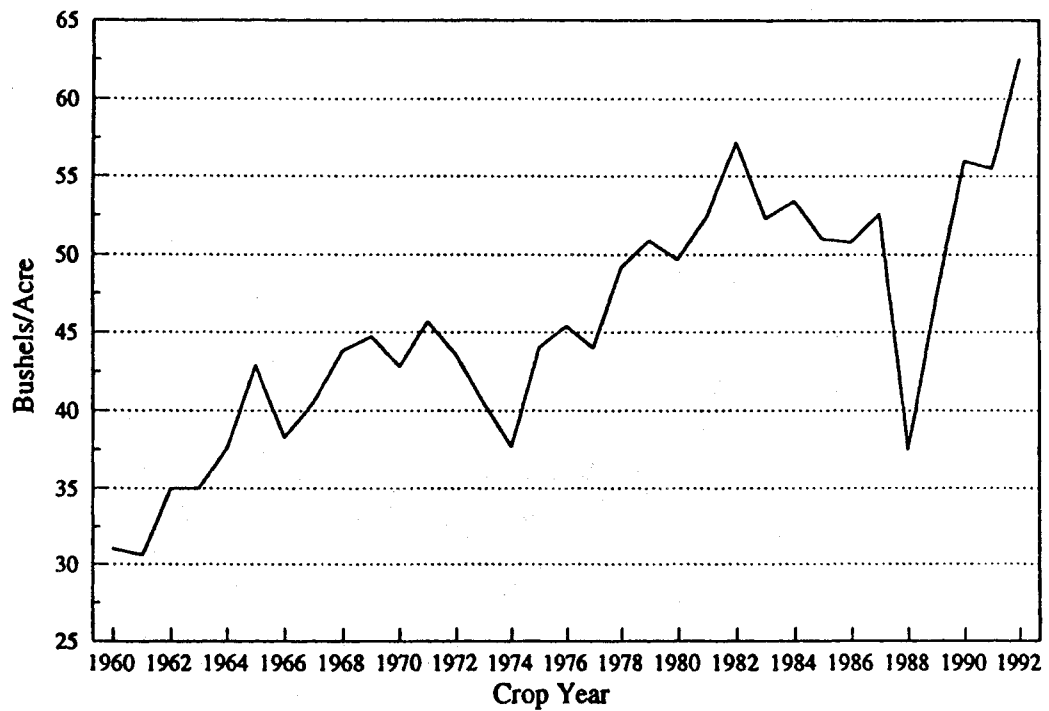


Figure 4. U.S. Average Barley Yield.

Source: USDA(F).

Barley production is either 6-rowed or 2-rowed as malt or feed varieties (this is described in detail in the next section). In recent years, 6-rowed malting and 2-rowed feed varieties account for the largest and second largest shares, respectively, of the barley varieties grown in the United States (Figure 5). The proportion of feed varieties grown has increased since 1989, primarily because feed varieties have higher yields than do malting varieties. Barley breeders can breed for higher yields and better feed nutritional values when they do not have to worry about malting quality requirements.

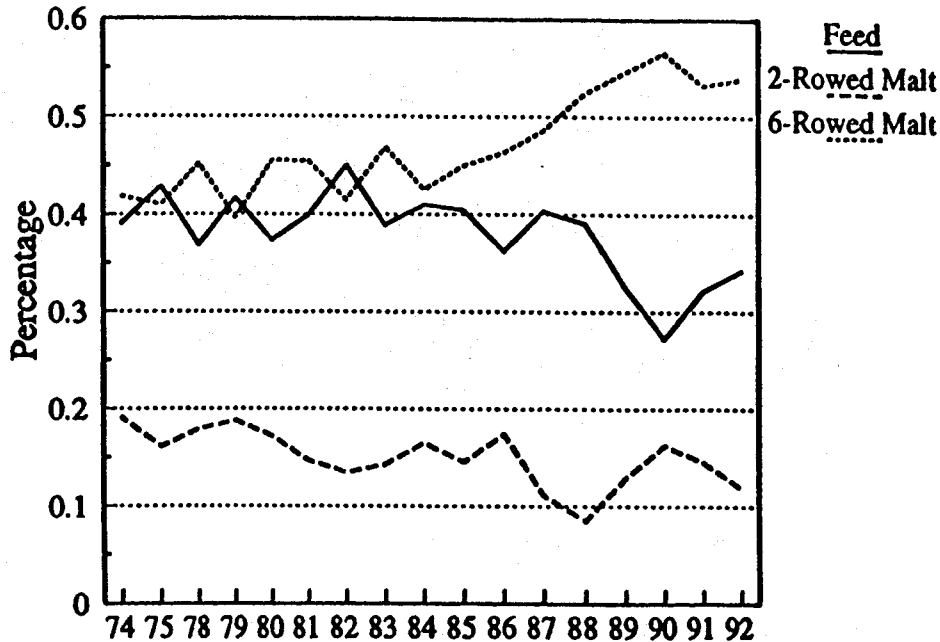


Figure 5. Acres of Barley Planted: By Type.

Source: American Malting Barley Association, Inc.

The majority of the malting varieties is grown in the Midwest states (Figure 6). Of these varieties grown in 1992, 6-rowed malting varieties accounted for approximately 55% of the acres grown and 2-rowed malting varieties accounted for approximately 12% of the acres (Figure 5).

Barley Use

Barley is used primarily in the malt and feed industries in both the domestic and export markets.

Malt Demand

Barley continues as an important crop because it "has several advantages as a malt over both wheat and rye" (Fleischmann-Kurth Malting Company):

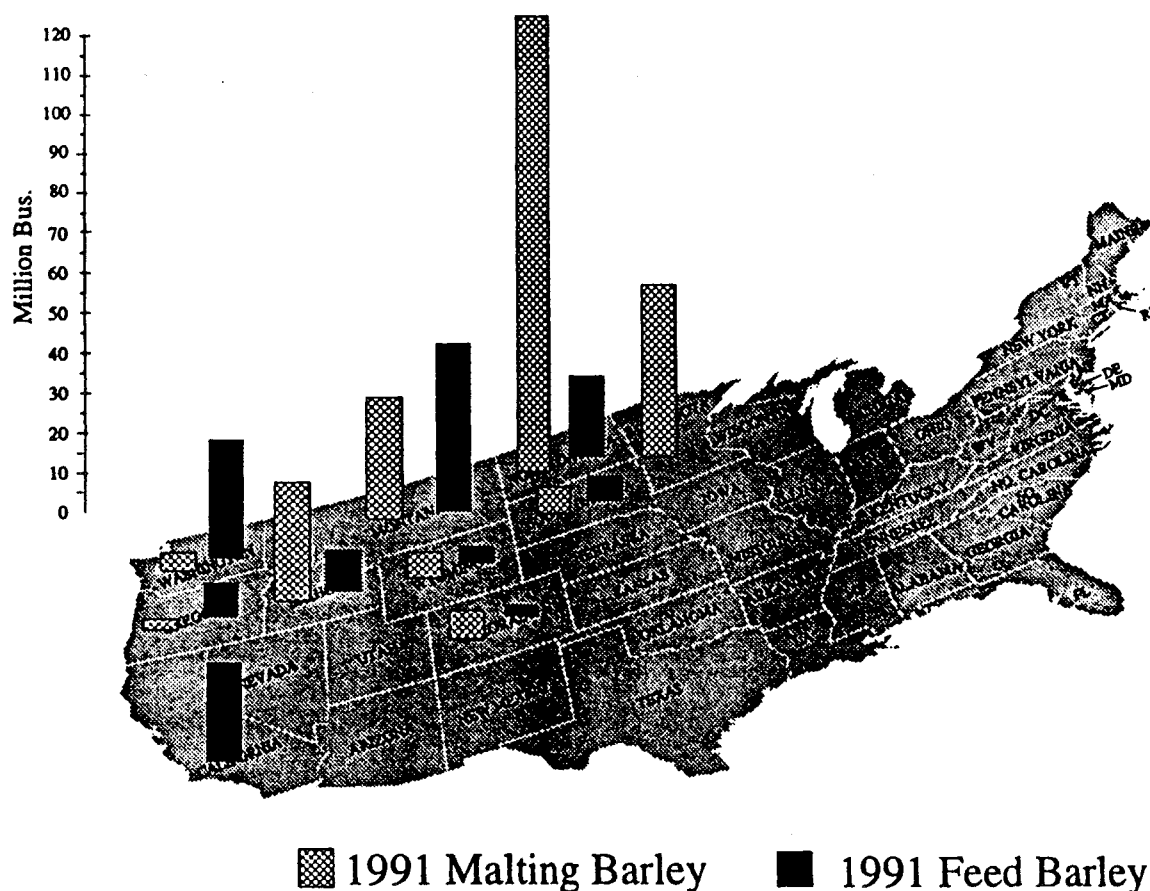


Figure 6. Malting and Feed Barley Production: By State.

Source: American Malting Barley Association, Inc.

1. It produces higher levels of enzymes than wheat or rye.
2. It has a husk in place to help protect the kernel during malting and subsequent handling. The husk also acts as a filter mat in wort preparation for the brewing, distilling, and cereal industries.
3. It produces a characteristic "malty" flavor and aroma that is not the same as that of the other grains.
4. It has been bred over the years to produce the above advantages while the other grains have not.

The amount of barley used in the malting industry (beer and alcohol) is constant (Figure 7). Per capita consumption of malt beverages reached a peak in the early 1980s and has been slowly decreasing (Figure 8). However, continued growth in the adult population has increased total demand for malt beverages.

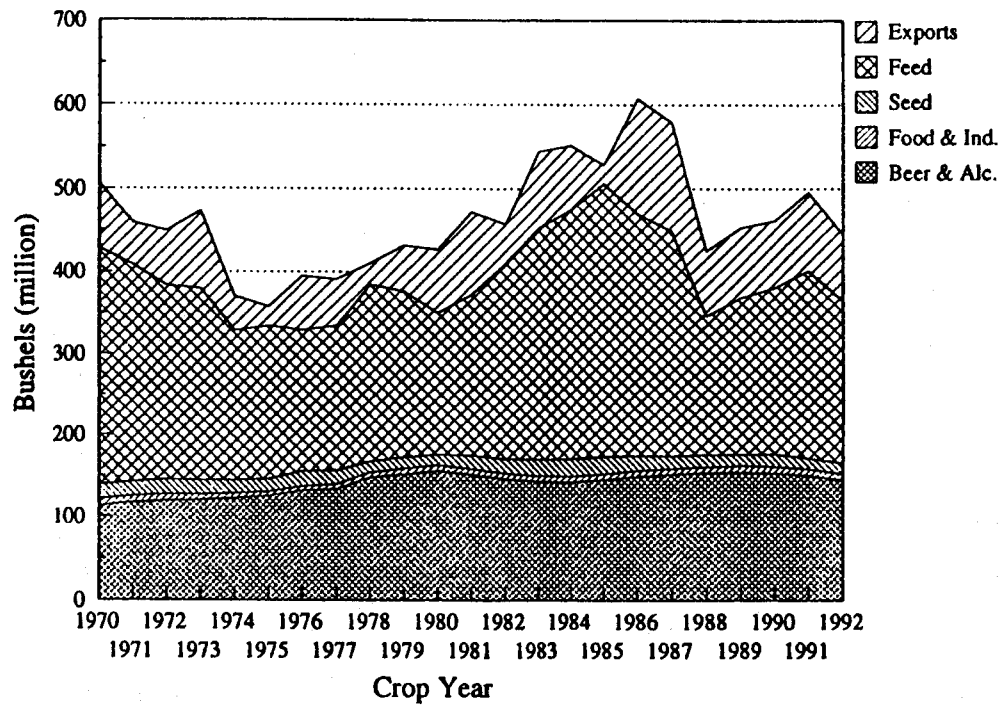


Figure 7. U.S. Barley Disappearance.

Source: USDA(G).

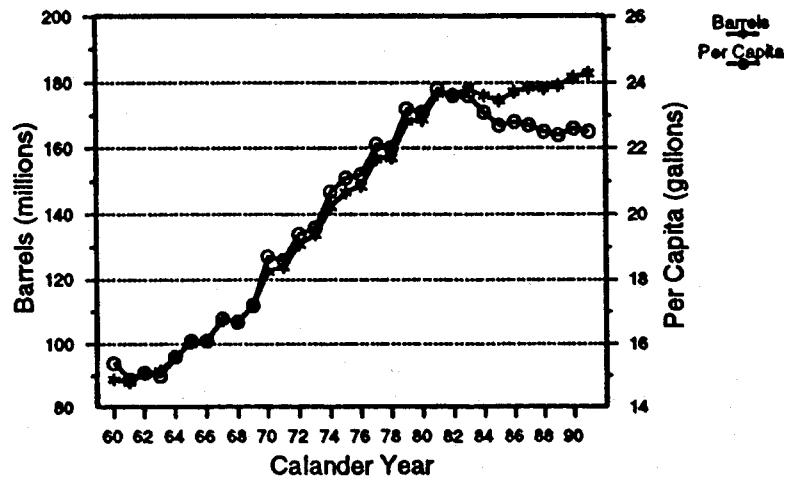


Figure 8. U.S. Consumption of Malt Beverages.

Source: Beer Institute.

Feed Demand

Barley is a good source of energy and nutrients for many animal groups.

Competition among feed ingredients depends primarily on relative price and relative energy value. The percentage of metabolizable energy in barley is slightly less than corn and sorghum averaged across all livestock classes. Barley is equivalent to corn in terms of feed value when fed to ruminants like dairy and beef cattle and sheep. Barley's high fiber content makes it less palatable and digestible to young swine and poultry. (Ash and Hoffman, p. 4)

Johnson and Varghese developed a model to analyze demand for feed barley for individual animal groups in the Upper Midwest. The analysis was based on the least-cost feed formulation. Nutritional requirements and prices of barley and competing feedstuff were incorporated into the analysis. Results indicated the extent that feed barley is substitutable with corn and other ingredients in regional demands. The cross-price elasticity with other protein sources, such as soybean and sunflower meal, was significant. Also, this model identified sources of economic value for particular livestock rations, and sensitivity analysis was used to illustrate the significance of barley nutritional characteristics on feed demand.

Feed accounts for the greatest use of barley followed closely by beer and alcohol use (Figure 7). "Over three-fourths of the barley fed is for ruminants: beef cattle in the Northern Plains and Southwest, and cattle and sheep in the Pacific Mountain States" (Ash and Hoffman, p. 4). Barley used as feed is reported as a residual from malting and alcohol, food and industrial, and seed use in estimates made by the U.S. Department of Agriculture. Variability of feed use is greater than that of other domestic uses.

Barley Exports

Barley exports from the United States have been erratic since 1960 (Figure 9), though increases have occurred. EC-12 was the largest purchaser of barley from the United States in the 1960s--however, their purchases have diminished to virtually nil. Saudi Arabia started to buy feed barley in the late 1970s and accounts for the majority of the barley exported from the United States.

Malting barley has ranged from 0.16% to 8.55% of total barley exported (Figure 10). Since 1988, Israel, Japan, and Mexico have accounted for most of the malting barley exported.

The Export Enhancement Program (EEP), a program in which the U.S. government subsidizes the sale of agricultural products, has been important to the sale of barley and barley malt. From 1985/86 to 1991/92, the percent of barley and barley malt sold under EEP has been 84% of total exports (Table 1).

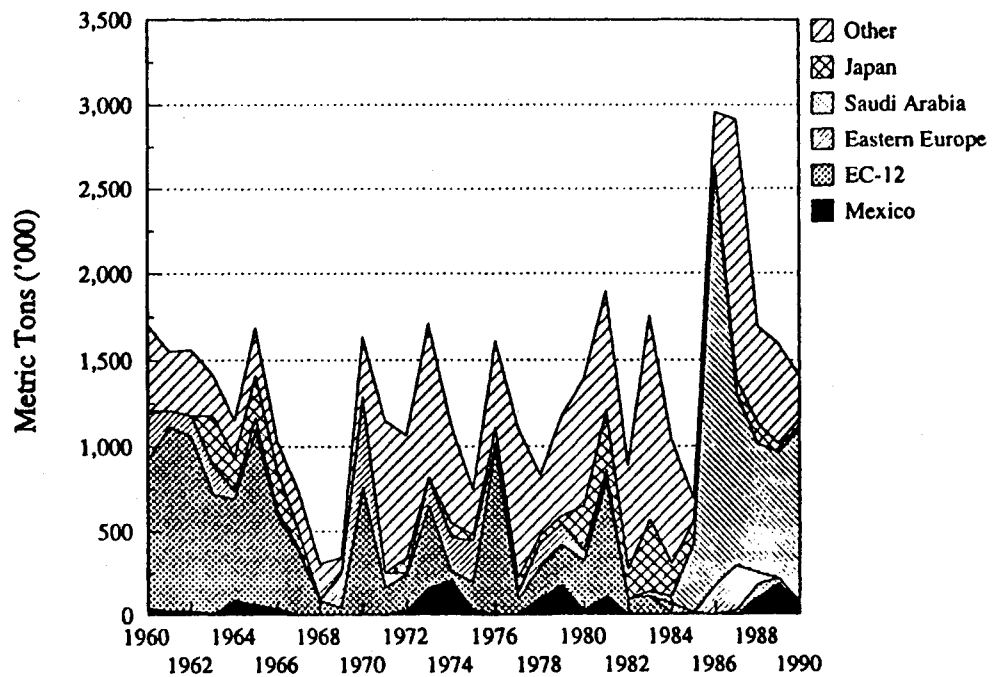


Figure 9. U.S. Barley Exports.

Source: Gudmunds and Webb.

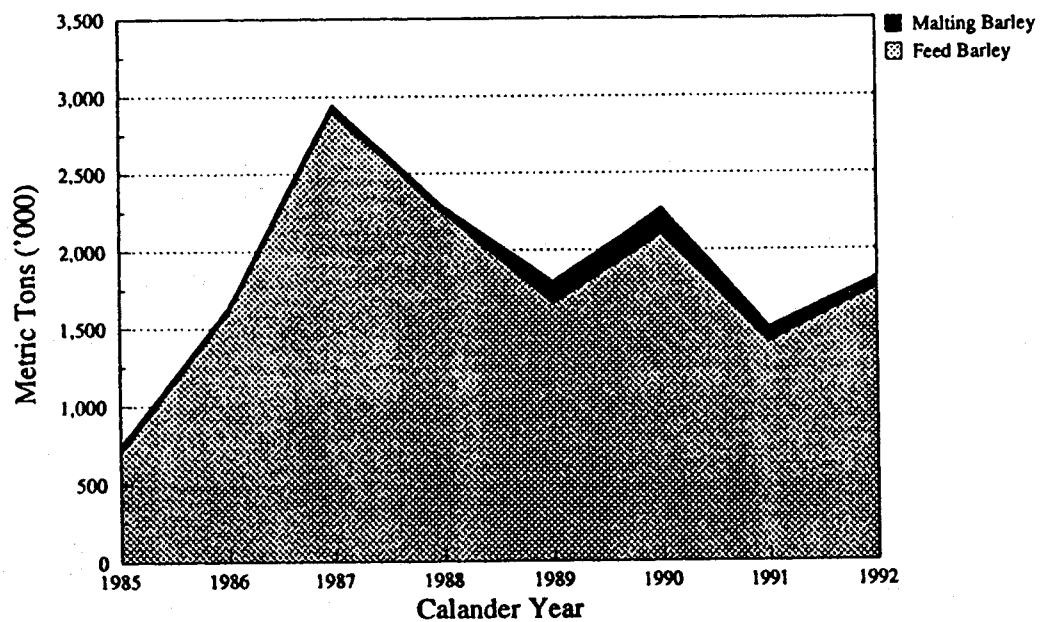


Figure 10. U.S. Exports of Feed and Malting Barley.

Source: USDA(I).

TABLE 1. EEP USE FOR U.S. BARLEY
(1985/86 TO 1991/92)

	Barley
Initiatives (000 mt)	14,650
Sales under EEP (000 mt)	11,436
Sales of initiatives (%)	78
Total exports (1985/86-1991/92) (000 mt)	13,586
Sold under EEP (%)	84
EEP bonus weighted average (mt)	\$34

SOURCE: Derived from unpublished
USDA data sources.

Quality:
Standards, Measurements, and Comparisons

Compared to other grains, barley is somewhat unique in that varieties are grown for different end uses.⁴ Grade standards, industry specifications, and geographical growing regions each reflect barley produced with different end-use characteristics. The purpose of this section is to describe the U.S. grade standards used in barley, with emphasis on dockage. Selected comparisons are made also to the Canadian grading system. Finally, barley quality data are analyzed to show correlations among quality characteristics.

Barley Differences

In the U.S. grading system, barley is classified as either 2-rowed or 6-rowed. "The terms six-rowed and two-rowed refer to the number of rows of grain seen when the ears are viewed from above" (Briggs, p. 68). Both 2-rowed and 6-rowed barley varieties have three spikelets per node. In 2-rowed barley, only the central spikelet is fertile and able to produce one kernel per node. In 6-rowed barley, all three spikelets are fertile and can produce three kernels per node (Briggs).

In two-rowed barleys, with only the central spikelet being fertile, the grains are uniformly symmetrical.... In six-rowed varieties all three spikelets at each node are fertile. The median grains, one third of the total number, are symmetrical but the remainder, the lateral grains, are unsymmetrical to a greater or lesser extent, each with a right-handed or left-handed bias. (Briggs, pp. 53-54)

⁴However, this is an apparent growing trend in other grains (Wheat and Wilson).

Six-rowed barley is generally less plump than 2-rowed barley because three kernels grow from the same node. Two-thirds (the lateral grains) of the kernels in 6-rowed barley are twisted around the median kernel. This crowded growing area in 6-rowed barley produces smaller kernels than 2-rowed barley where only one kernel is produced per node.

U.S. Grade Standards and Marketing Practices

U.S. grain standards, administered by the Federal Grain Inspection Service (FGIS), are used to determine barley grades. However, market participants in the barley industry, similar to other grain sectors, use their own specifications. Class, subclass, and barley variety are important in grain standards and the barley marketing industry. Most grain for export must be officially weighed and inspected if marketed under a U.S. grade. Inspection for grain handled at inland locations is provided on a request basis.

FGIS, an agency of USDA, was created in 1976 under Public Law 94-582, an amendment to the Grain Standards Act (Hill).

This government agency (FGIS) administers a nationwide system for officially inspecting and weighing grain and other commodities. It provides services through FGIS field offices in 23 states and Canada. FGIS field offices also oversee performance of state and private agencies which provide official services at other domestic grain markets. (U.S. Wheat Associates, p. 3)

Grain Standards

Barley is classified by varieties, either feed or malting. Both 2-rowed and 6-rowed barley have feed and malting varieties. Malting varieties are those that the American Malting Barley Association, Inc. (AMBA) approves for malting. Varieties are approved to be grown for malting purposes in specific states. Not all barley production from malting varieties is suitable for malting. Many farmers plant malting varieties, expecting to meet malting requirements; however, if they do not, they are sold as feed barley.

For grading, FGIS groups barley into three classes of 6-rowed barley, 2-rowed barley, and barley [USDA(B)]. Six-rowed and 2-rowed barley classes are divided into subclasses (Figure 11). Subclasses of 6-rowed malting barley, 6-rowed blue malting barley, and 2-rowed malting barley meet grade standards for that particular malting subclass and are varieties that the AMBA has recommended as suitable for malting and brewing. Grade requirements for the subclasses of 6-rowed malting barley, 6-rowed blue malting barley, and subclass 2-rowed malting barley are presented in Tables 2 and 3.

The subclasses of 6-rowed barley and 2-rowed barley are for barley that does not meet requirements of malting barley subclasses for that particular variety [USDA(B)]. The class barley is defined as "barley that does not meet the requirements for the classes six-rowed barley and two-rowed barley" [USDA(B), p. B-2]. Grade requirements for the subclasses 6-rowed barley, 2-rowed barley, and class barley are presented in Table 4.

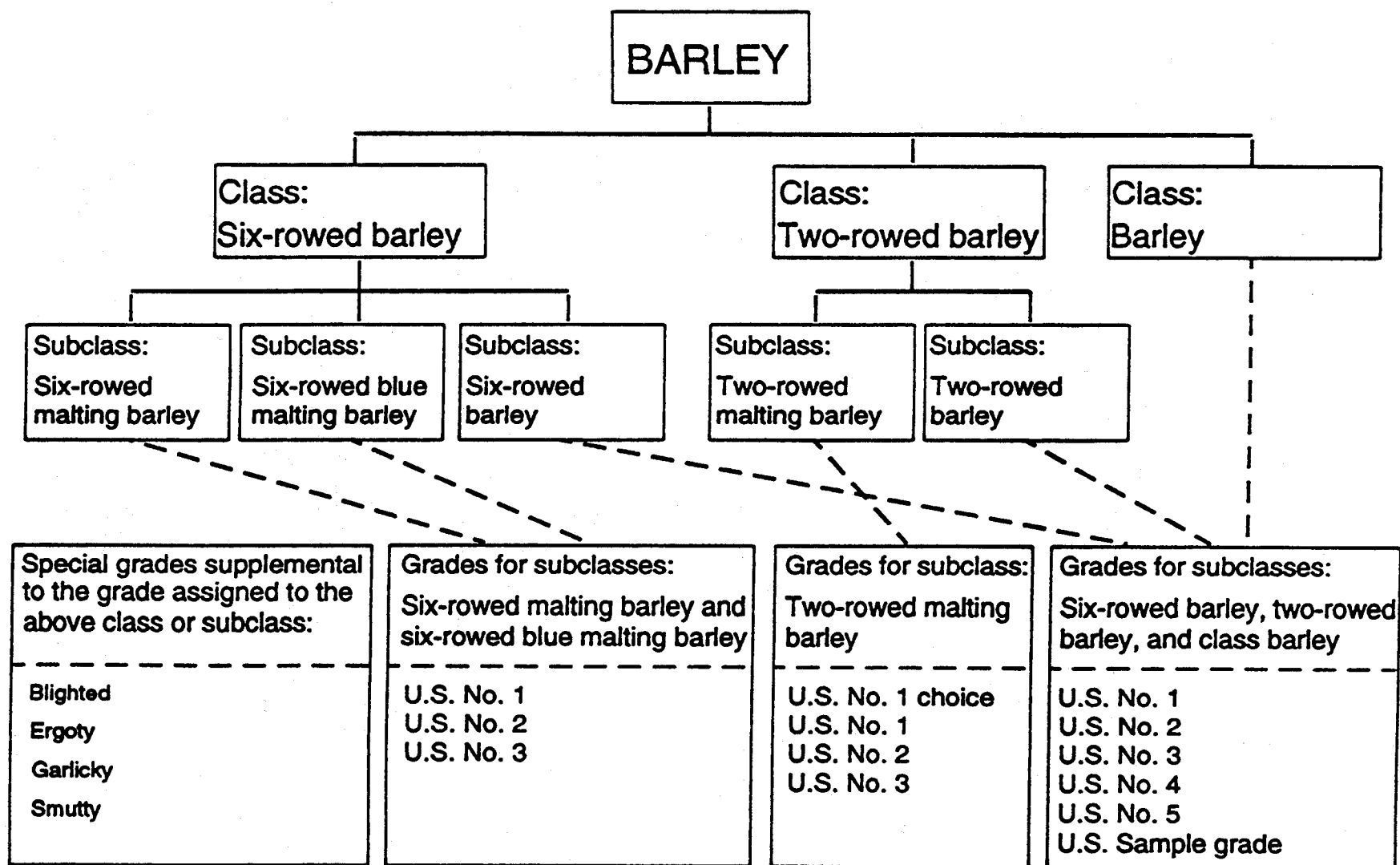


Figure 11. Barley Classes, Subclasses, and Special Grades.

Source: Adapted from Walter G. Heid Jr. and Mack N. Leath. February 1978. *U.S. Barley Industry*. Agricultural Economics Report No. 395. U.S. Department of Agriculture/Economics, Statistics, and Cooperative Service, Washington, DC.

TABLE 2. OFFICIAL U.S. GRADE REQUIREMENTS FOR THE SUBCLASSES OF SIX-ROWED MALTING BARLEY AND SIX-ROWED BLUE MALTING BARLEY

Grade ^a	Minimum Limits Of			Maximum Limits Of				
	Test Weight Per Bushel	Suitable Malting Type	Sound Barley ^b	Damaged Kernels ^b	Foreign Material	Other Grains	Skinned and Broken Kernels	Thin Barley
	pounds				percent			
U.S. No. 1	47.0	95.0	97.0	2.0	1.0	2.0	4.0	7.0
U.S. No. 2	45.0	95.0	94.0	3.0	2.0	3.0	6.0	10.0
U.S. No. 3	43.0	95.0	90.0	4.0	3.0	5.0	8.0	15.0

^aSix-rowed malting barley and six-rowed blue malting barley may contain not more than 1.9% of injured-by-frost kernels that may include not more than 0.4% of frost-damaged kernels; not more than 0.2% of injured-by-heat kernels that may include not more than 0.1% of heat-damaged kernels; that is not blighted, ergoty, garlicky, infested, or smutty; and that otherwise meet the grade requirements of the subclass six-rowed malting barley and six-rowed blue malting barley; and may contain unlimited amounts of injured-by-mold kernels; however, mold-damaged kernels are scored as damaged kernels and against sound barley limits.

^bInjured-by-frost kernels and injured-by-mold kernels are not considered damaged kernels or scored against sound barley.

SOURCE: USDA(B).

TABLE 3. OFFICIAL U.S. GRADE REQUIREMENTS FOR THE SUBCLASS TWO-ROWED MALTING BARLEY

Grade ^a	Minimum Limits Of			Maximum Limits Of			
	Test Weight Per Bushel	Suitable Malting Type	Sound Barley ^b	Wild Oats	Foreign Material	Skinned and Broken Kernels	Thin Barley
	- pounds -						
Choice	50.0	97.0	98.0	1.0	0.5	5.0	5.0
U.S. No. 1	48.0	97.0	98.0	1.0	0.5	7.0	7.0
U.S. No. 2	48.0	95.0	96.0	2.0	1.0	10.0	10.0
U.S. No. 3	48.0	95.0	93.0	3.0	2.0	10.0	10.0

^aTwo-rowed malting may contain not more than 1.9% of injured-by-frost kernels that may include not more than 0.4% frost-damaged kernels; not more than 1.9% of injured-by-mold kernels that may include not more than 0.4% of mold-damaged kernels; and not more than 0.2% of injured-by-heat kernels that may include not more than 0.1% of heat-damaged kernels; that is not blighted, ergoty, garlicky, infested, or smutty; and that otherwise meet the grade requirements of the subclass two-rowed malting barley.

^bInjured-by-frost kernels and injured-by-mold kernels are not scored against sound barley.

SOURCE: USDA(B).

TABLE 4. OFFICIAL U.S. GRADE REQUIREMENTS FOR THE SUBCLASSES SIX-ROWED BARLEY, TWO-ROWED BARLEY, AND THE CLASS BARLEY

Grade	Minimum Limits Of		Maximum Limits Of				
	Test Weight Per Bushel	Sound Barley	Damaged Kernels ¹	Heat Damaged Kernels (Major)	Foreign Material	Broken Kernels	Thin Barley
	- pounds -			percent			
U.S. No. 1	47.0	97.0	2.0	0.2	1.0	4.0	10.0
U.S. No. 2	45.0	94.0	4.0	0.3	2.0	8.0	15.0
U.S. No. 3	43.0	90.0	6.0	0.5	3.0	12.0	25.0
U.S. No. 4 ²	40.0	85.0	8.0	1.0	4.0	18.0	35.0
U.S. No. 5	36.0	75.0	10.0	3.0	5.0	28.0	75.0
U.S. Sample Grade							

U.S. Sample grade shall be barley that:

- (a) Does not meet the requirements for the grades U.S. No. 1, 2, 3, 4, or 5; or
- (b) Contains 8 or more stones or any number of stones which have an aggregate weight in excess of 0.2% of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria* spp.), 2 or more castor beans (*Ricinus communis* L.), 4 or more particles of an unknown foreign substance(s) of commonly recognized harmful or toxic substance(s), 8 or more cocklebur (*Xanthium* spp.) or similar seeds singly or in combination, 10 or more rodent pellets, bird dropping, or equivalent quantity of other animal filth per 1-1/8 to 1-1/4 quarts of barley; or
- (c) Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
- (d) Is heating or otherwise of distinctly low quality.

¹Includes heat-damaged kernels. Injured-by-frost kernels and injured-by-mold kernels are not considered damaged kernels.

²Barley that is badly stained or materially weathered shall not be graded higher than U.S. No. 4.

SOURCE: USDA(B).

Grade standards provide a uniform method to describe barley, based on its physical characteristics. Numerical grades are used to convey quality attributes and facilitate transactions. The lowest quality factor of any attribute determines the numerical grade.

Industry Practices

Individual market participants have requirements that are sometimes not measured within the U.S. grade standards, such as protein, color, plumpness, and dockage. However, these are important determinants of value for the market system. Standard FGIS methodologies exist for measuring these attributes, and results are reported on official grade certificates.

Barley, which the malting industry uses, contains varieties that the AMBA recommended or nonrecommended varieties that are grown under contract for particular maltsters. In either case, barley quality must meet the maltsters' standards. Some maltsters contract for specific barley varieties to assure a supply of that variety. Contracting is more prevalent in the mountain states (Colorado, Idaho, and Montana) because feed varieties generally have higher yields than

malting varieties and because of higher-value competing crops. Maltsters have made extensive use of preplanting contracts in these regions to entice producers to raise particular varieties.

Barley quality changes from year to year and from region to region. Buyers also purchase barley based on location in recognition of effects of climatic and agronomic conditions on quality characteristics. Attributes that maltsters strive for are varietal purity, high germination and high plumpness, low protein level, and low kernel damage (Fleischmann-Kurth Malting Company).

Barley used for livestock feed is generally a residual (that not used for food, malting, and seed) and competes with other feed grains, mainly corn. The price and nutritional characteristics of barley relative to the price and nutritional characteristics of other feedstuffs determine the quantity of barley used as a feed grain.

Canada Grade Standards and Marketing Practices

The Canadian Grain Commission (CGC) has similar responsibilities to the FGIS.

The Canadian Grain Commission is a government organization responsible to the federal Minister of Agriculture. Under the authority of the 1971 Canada Grain Act, the Commission sets the standards for Canadian grain quality and insures that the standards are maintained as grain moves through the handling and transportation system. (Forbes, p. 17)

The Grain Inspection Division of CGC is responsible for grading grain in Canada.

The grading systems between these two countries with respect to barley has three important differences. First, in Canada, the CGC determines a list of registered varieties for each grade (6-rowed malting, 2-rowed malting, and 6- and 2-rowed feed). Variety registration is determined through a committee process, including representatives from industry, government, and universities, who jointly consider agronomic, pathological, and quality characteristics of proposed new varieties.⁵ To be marketed as any of these grades, the variety must be registered. If a variety is not registered, it will be assigned the lowest grade in its class, thereby deterring production. Other varieties (e.g., 6-rowed white aleurone) may be produced under special contracting programs.

Second, export shipments have a separate grade standard. Third, dockage is not a grade-determining factor in either country. However, in Canada, regulations ensure that all dockage is cleaned from barley at terminal elevators and that barley is designated "commercially clean."

⁵The Barley and Malting Research Institute publishes data on varieties grown and area planted to each in Canada.

Grain Standards

Like the United States, barley is classified in Canada as feed or malting varieties. These are both 2-rowed or 6-rowed malting barley varieties. Canada, like the United States, has domestic grade standards for both malting and feed barley. However, unlike the United States, Canada has a separate standard for export barley that, for most factors, is stricter and results in higher quality than the domestic standard.

The grade standards for feed and malting barley are presented in Tables 5 and 6.

Grades of barley are divided into two classes: select and general purpose. Select grades are those designated "Special Select" of "Select," e.g., "Barley, Special Select C.W./C.E. Two-row." General purpose grades are those designated "No. 1" of "No. 2," e.g., "Barley, No. 1 C.W./C.E.." Only barley accepted for malting purposes may be assigned a select grade. Barley accepted for malting that does not qualify for the select grade specifications is graded "Barley, Sample Select C.W./C.E., Two Row/Six Row." Barley not accepted for malting is assigned a general Purpose Grade, i.e., "C.W." of "C.E." (Canadian Grain Commission, p. 1)

Grades for export barley are determined with separate grade standards (Table 7). Important differences exist between the domestic and export standards. The export standard has tighter limits on both total foreign material for the C.W. grades and treatment of removable material.

"Removable material," which is most similar to dockage, is also referred to as "aspirated material"⁶ and is restricted to 0.2% for each grade in the export standard. In the United States, removable material is defined as dockage, is not a grade-determining factor, and is a negotiable term. In Canada, the regulation that induces commercial cleaning is uniform factor limits for removable material across grades and classes. Because of this configuration of factor limits, all exported barley is cleaned commercially to conform to these standards. However, barley sold under the primary standards, including domestic sales and exports to the United States, generally are not cleaned before shipment.

Definitions of Quality Characteristics: United States

Some quality characteristics are used to determine official grades. Other quality characteristics, e.g., dockage, are reported on official grade certificates, but are not used in determining the official grade. Each is described below.

⁶Aspirated material is created in the handling process.

TABLE 5. CANADIAN PRIMARY STANDARDS: SELECTED BARLEY

Grade Name	Degree of Soundness	Varietal Standard	Other Classes or Nonregistered Varieties	Sprouted	Heavy, Rotted Severe Mildew	Fire-burnt	Frost Damage	Peeled and Broken	Plump	Thin
Special Select C.W./C.E. Two-Row	Reasonably sound, fairly well matured, may be moderately weather-stained but not severely discolored	Any two-rowed variety equal for malting purposes to Klages	5.0%	Nil	Nil	Nil	0.2%	5.0%	80.0%	4.0%
Special Select C.W./C.E. Six-Row		Any six-rowed variety equal for malting purposes to Bonanza							70.0%	5.0%
Select C.W./C.E. Two-Row	Fairly sound, may be slightly immature and moderately weather-stained or discolored	Any two-rowed variety equal for malting purposes to Klages	10.0%	0.5%	0.2%	Nil	2.0%	7.0%	75.0%	4.0%
Select C.W./C.E. Six-Row		Any six-rowed variety equal for malting purposes to Bonanza							65.0%	5.0%

Grade Name	Minimum Test Weight	Foreign Material						
		Inseparable Seeds	Wild Oats	Other Cereal Grain	Stones	Ergot	Sclerotinia	Total Foreign Material
Special Select C.W./C.E. Two-Row	63.0 kg/hL	All grades about 0.2% but free of large oil-bearing seeds	0.5%	1.5%	2K	Nil	0.01%	1.5%
Special Select C.W./C.E. Six-Row	62.0 kg/hL							
Select C.W./C.E. Two-Row	61.0 kg/hL		1.0%	3.0%	2K	3K	0.01%	4.0%
Select C.W./C.E. Six-Row	60.0 kg/hL							

Only barley accepted for malting purposes may be graded into the "select" grades. Barley accepted for malting that does not qualify for the "select" grade specifications is graded "Barley, Sample Select C.W./C.E. Two-Row or Six-Row." Barley not selected for malting is graded according to quality into the "general purpose" grades.

NOTE: THE LETTER "K" IN THESE TABLES REFERS TO KERNELS OR KERNEL SIZE PIECES IN 500 GRAMS.

TABLE 6. CANADIAN PRIMARY STANDARDS: FEED CLASSES

Grade Name	Degree of Soundness	Variety	Sprouted	Heated, Rotted and Severely Mildewed	Fireburnt	Frost Damage	Broken	Plump	Thin
No. 1 C.W./C.E.	Frosted, weather-stained or otherwise damaged but reasonably sweet	Any acceptable reference varieties	10.0%	1.0%	Nil	No Limit	15.0%	No Limit	
No. 2 C.W./C.E.	Excluded from other grades of barley on account of test weight, immature or severely damaged kernels, but considered fairly sweet	Any variety or type or combination of varieties or types	20.0%	10.0%	0.5%	No Limit	25.0%	No Limit	
If specs for No. 2 C.W./C.E. are not met, grade			Barley, Sample C.W./C.E., Account Sprouted	Barley, Sample C.W./C.E., Account Heated	Barley, Sample C.W./C.E., Account Fireburnt		Barley, Sample Broken Grain		

Grade Name	Minimum Test Weight	Foreign Material						
		Inseparable Seeds	Wild Oats	Other Cereal Grain	Stones*	Ergot	Sclerotinia	Total Foreign Material
No. 1 C.W./C.E.	58.0 kg/hL	About 0.2%	3.0%	5.0%	5K	0.05%	0.01%	5.0%
No. 2 C.W./C.E.	54.0 kg/hL	About 0.2%	10.0%	15.0%	5K	0.10%	0.01%	15.0%
If specs for No. 2 C.W./C.E. are not met, grade	Barley, Sample C.W./C.E., Account Lightweight	Barley, Sample C.W./C.E., Account Admixture	Up to 50.0% Mixed Grain, C.W./C.E. Barley	Mixed Grain, C.W./C.E. Barley	Over grade tolerance up to 2.5%; Barley Rejected (grade) Account Stones. Over 2.5%: Barley, Sample Salvage	Barley, Sample C.W./C.E., Account Ergot	Barley, Sample C.W./C.E., Account Admixture	Mixed Grain, C.W./C.E. Barley

*For Canada Eastern barley, refer to the section of the text dealing with stones.

NOTE: THE LETTER "K" IN THESE TABLES REFERS TO KERNELS OR KERNEL SIZE PIECES IN 500 GRAMS.

TABLE 7. CANADIAN BARLEY STANDARDS IN EXPORT GRADE DETERMINANTS

Grade Name	Foreign Material						Heated	Mineral Matter		Ergot	Sclerotia	Plump	Thin	Peeled and Broken
	Total Removable Material	Large Seeds	Wild Oats	Total Large Seeds & Wild Oats	Other Cereal Grains	Total		Stones	Total					
Special Select C.W. Two-Row	0.2% (including 0.1% small seeds)	0.2% (free of large oil-bearing seeds)	0.5%	Only individual tolerances are applied	1.5%	1.5%	Nil	0.02%	.033%	Nil	0.01%	80.0%	4.0%	6.0%
Special Select C.W. Six-Row												70.0%	5.0%	
Select C.W. Two-Row	0.2% (including 0.1% small seeds)	0.5% (free of large oil-bearing seeds)	1.0%	Only individual tolerances are applied	3.0%	4.0%	0.1%	0.02%	.033%	.025%	0.01%	75.0%	4.0%	7.0%
Select C.W. Six-Row												65.0%	5.0%	
No. 1 C.W.	0.2% (including 0.1% small seeds)	0.5% (including large oil-bearing seeds)	1.5%	1.5%	4.0%	4.0%	0.5%	0.15%	0.25%	0.05%	0.01%	No limit		<u>Broken</u> 15.0%
No. 2 C.W.	0.2% (including 0.1% small seeds)	0.5% (including large oil-bearing seeds)	2.5%	2.5%	10.0%	10.0%	2.5%	0.15%	0.25%	0.10%	0.01%			25.0%

Foreign Material

Foreign material is a grade-determining factor. Foreign material is "all matter other than barley, other grains, and wild oats that remains in the sample after removal of dockage" [USDA(B), p. B-2].

Plump and Thin Barley

Plump barley is a nongrade-determining factor, while thin barley is a grade-determining factor. Plump barley is defined as "barley that remains on top of a 6/64 x 3/4 slotted-hole sieve after sieving according to procedures prescribed in FGIS instructions" [USDA(B), p. B-3].

Thin barley (thins) is defined as "six-rowed barley which passes through a 5/64 x 3/4 slotted-hole sieve and two-rowed barley which passes through a 5.5/64 x 3/4 slotted-hole sieve after sieving according to procedures prescribed in FGIS instruction" [USDA(B), p. B-4]. The larger sieve used to determine thins in 2-rowed barley reflects that 2-rowed barley is generally plumper than 6-rowed barley because of its anatomical characteristics.

Protein

Protein is an official criterion and a nongrade-determining factor. Thus, it does not have to be reported on the certificate, but is available on request.

Skinned and Broken Kernels

Skinned and broken kernels is a grade-determining factor for malting subclass. Skinned and broken kernels is defined as "barley kernels that have one-third or more of the hull removed, or that the hull is loose or missing over the germ, or broken kernels, or whole kernels that have a part or all the germ missing" [USDA(B), p. B-4].

Sound Barley

Sound barley is a grade-determining factor and is defined as "kernels and pieces of barley kernels that are not damaged" [USDA(B), p. B-4].

Test Weight

Test weight is a grade-determining factor. Test weight is defined as "the weight per Winchester bushel (2,150.42 cubic inches) as determined using an approved device according to procedures prescribed in FGIS instructions" [USDA(B), p. A-1]. Test weight for barley "is determined after mechanically cleaning the original sample" [USDA(B), p. A-1]. "Test weight per bushel for all other grains (barley) is recorded in whole and half pounds, with fractions of a half pound disregarded" [USDA(B), p. A-1].

Dockage in the United States: Standards and Industry Practices

Canada and the United States each have unique dockage definitions, and the barley industry sometimes differs from the official standard when it measures dockage. Dockage standards as applied to barley in each country are discussed in the next two sections, including comparisons of U.S. and Canadian standards.

Standards

FGIS defines dockage as

All matter other than barley that can be removed from the original sample by use of an approved device according to procedures prescribed in FGIS instructions. Also, underdeveloped, shriveled, and small pieces of barley kernels removed in properly separating the material other than barley and that cannot be recovered by properly rescreening or recleaning. [USDA(B), p. B-2]

The amount of barley needed to determine the dockage level is a sample of approximately 1-1/8 to 1-1/4 quarts. A Carter-Day Dockage Tester is the "approved device" for determining dockage levels [USDA(A)].

FGIS reports dockage as "the percentage of dockage on the certificate in whole percent with a fraction of a percent disregarded" [USDA(A), p. 2-14]. For example

0 to 0.99% dockage is reported as 0% dockage
1.00 to 1.99% dockage is reported as 1.0% dockage
2.00 to 2.99% dockage is reported as 2.0% dockage

This reporting procedure is of critical importance to foreign buyers who must rely on official inspection certificates and has the effect of underreporting the actual dockage level.⁷

Industry Practices

Barley handlers use the Carter-Day Dockage Tester to determine dockage levels; however, alternative means are sometimes used. The purpose is to "identify and encourage the use of practical, cost-effective procedures for conducting commercial grain inspections" [USDA(E), Preface]. Alternative methods are not approved for "official inspections," but are used regularly in commercial transactions and give similar results to the Carter-Day Dockage Tester.

The most common alternative is hand sieves. This procedure requires a 5/64-inch triangular-hole sieve nested on top of a bottom pan. The sample of barley is poured into the center of the triangular-hole sieve. The sieve and bottom pan can be placed on a

⁷Similar procedures were used in wheat. However, these were changed in May 1987, following foreign buyer complaints of underreporting dockage levels.

mechanical shaker or moved back and forth by hand. A mechanical shaker should be set to give 20 strokes. If the sieving is done by hand, the pan is kept level and shaken from right to left at a distance of 10 inches for 20 times [USDA(E)]. Dockage is considered "to be all coarse material that remains on top of the sieve and all material that passed through the bottom sieve" [USDA(E), p. 25].

Dockage in Canada

Standards

Dockage is defined as

... material that must be removed from grain by the use of approved cleaning equipment in order that the grain can be assigned the highest grade for which it qualifies (Canadian Grain Commission, p. 3).

The amount of barley needed to determine the dockage level is approximately 1,000 grams for an official sample and 500 grams for an unofficial sample. Dockage can be determined with a manual or mechanical method. The manual method consists of three hand sieves. The mechanical method designates the Carter-Day Dockage Tester as the appropriate device for determining dockage levels (Canadian Grain Commission).

In reporting dockage levels, the following rules apply:

The percentage by weight of dockage in a sample is reported in increments of 0.5% when the grain is not commercially clean. In export shipments authorized by the Commission to contain dockage, dockage is reported to the nearest 0.1%. (Canadian Grain Commission, p. 3)

Comparison of Dockage Measurement in Canada and the United States

Standards in the United States require a minimum of 250 grams for determining dockage levels. The Carter-Day Dockage Tester, used to determine dockage levels in Canada and the United States, is the only approved device for determining official dockage levels in barley in the United States. The Carter-Day Dockage Tester was designed to meet U.S. Department of Agriculture specifications. The feed control, air control, riddle, and three sieves can be changed to adjust the tester for use in other grains (Figure 12).

Even though Canada and the United States both use the Carter-Day Dockage Tester to determine dockage levels, the feed and air controls are set at different values; and different size sieves are used in each country (Table 8). The feed rate is slower and the air rate is higher in Canada than in the United States, leading to the removal of more material called dockage.

To determine effects of differences in these methods, 25 samples of barley were sent to the respective country official grain testing agency. Samples of barley were provided by the North Dakota Barley Council, Busch Agricultural Resources, Inc., and NDSU's Department of

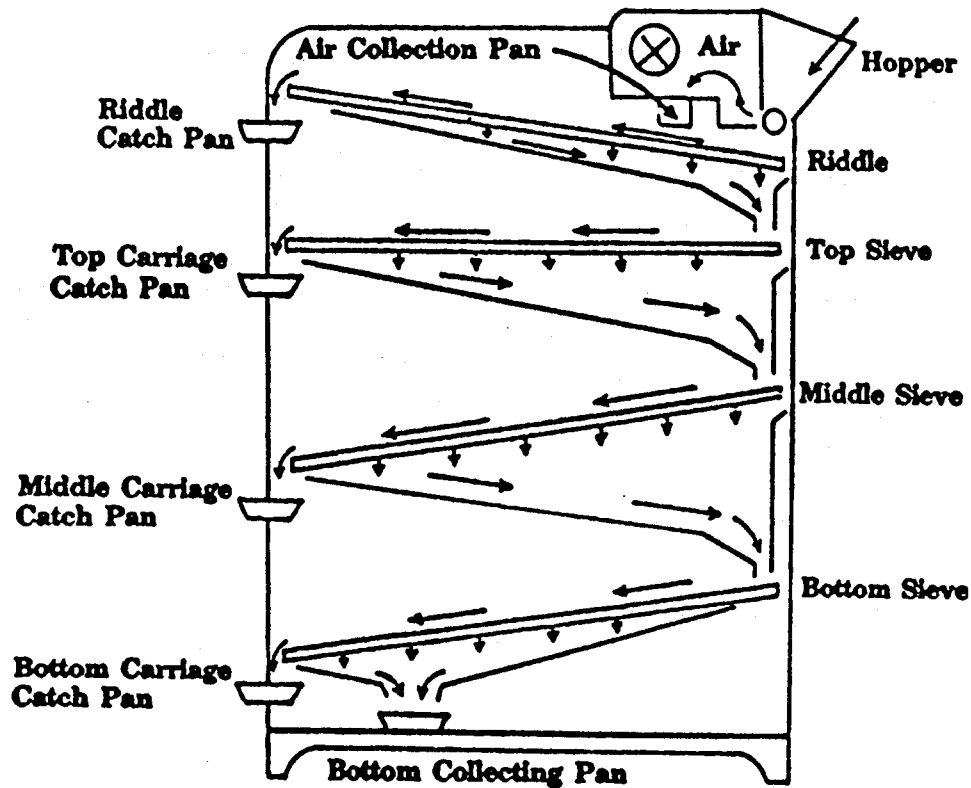


Figure 12. Carter-Day Dockage Tester Flow Chart.

Source: U.S. Wheat Associates.

TABLE 8. BARLEY SETTING OF THE CARTER-DAY DOCKAGE TESTER IN CANADA AND THE UNITED STATES

Setting	Canada	United States
Feed control	No. 5	No. 6
Air control	No. 6	No. 4
Riddle	No. 6	No. 6
Top sieve	No. 6 buckwheat	No. 8
Centre sieve	No. 5 buckwheat	No. 6
Bottom sieve	No. 4.5 round-hole	No sieve

SOURCE: Canadian Grain Commission and USDA(A).

Crop and Weed Sciences. The samples were divided into two 1,000-gram portions. One portion was sent to the CGC and the other to FGIS for official dockage tests.

These results are shown in Table 9. CGC always reported a higher dockage level than FGIS for the same sample. On average, the CGC dockage was 1.14%, compared to 0.69% for FGIS. The difference ranged from 0.04% to 1.20%. In all cases, the dockage level reported by the CGC exceeded that of FGIS. Results of the official CGC and FGIS tests indicate a significant difference in the amount of dockage reported for the same sample of barley (Table 10). The average difference in the reported dockage level was 0.45%, indicating a significant difference in a paired-comparison t-test. Thus, if CGC and FGIS report the same dockage level according to their official testing procedures, Canada's barley would have about 0.45% less dockage.

Malting and Brewing Requirements

The malting and brewing industry requires uniform barley quality. Malting barley quality is determined by variety, protein, plumpness and thins, germination, skinned, mold damage, blight damage, and color. Each of these characteristics affects the malting and brewing process.

Varietal purity is probably the most important because

Each variety of barley germinates and modifies at its own rate. Mixtures of varieties will cause a non-uniform conversion to malt. Malting conditions may be optimal for 1 of the varieties, but cause others to grow more slowly or more quickly. The major analytical parameters impacted by varietal impurity are: malt uniformity, endosperm modification and, depending upon the degree of varietal contamination, can affect all malt parameters. Also affected will be malt process efficiency and brewhouse performance." (Fleischmann-Kurth Malting Company)

Maltsters try to obtain barley with protein levels under 13.5%. However, "extremely low protein levels can cause problems as well, but not to as great an extent" as high protein (Fleischmann-Kurth Malting Company). "The major difficulty with utilizing high protein barley is its effect upon malt extract-- approximately 0.8% is lost for each 1% of additional total protein" (Fleischmann-Kurth Malting Company). In addition, the "beer flavor and mouth feel can also be affected by protein levels" (Lovas).

Maltsters prefer barley with high plump and low percentage of thins. Maltsters usually size (grade) barley before it is malted. Thin kernels that are removed are sold as either feed barley or needles. The maltster views buying malting barley and selling a portion of it at a lower price as a cost. Thin barley that is malted generally has the same impact on the malting and brewing process as high protein does (Lovas). This is because thin barley is highly correlated with protein levels.

TABLE 9. DOCKAGE LEVELS UNDER THE CANADIAN AND UNITED STATES
OFFICIAL TESTING PROCEDURES, 1993

Sample ^a	Variety	Row-type	Dockage Levels		
			Canada	U.S.	Diff.
1	Azure	6	0.10	0.05	0.05
2	Stark	2	0.25	0.21	0.04
3	Excel	6	0.28	0.10	0.18
4	Stark	2	0.34	0.24	0.10
5	Robust	6	0.36	0.23	0.13
6	Bowman	2	0.42	0.26	0.16
7	Robust	6	0.58	0.49	0.09
8	Robust	6	0.77	0.47	0.30
9	Robust	6	0.80	0.40	0.40
10	Excel	6	1.00	0.49	0.51
11	Excel	6	1.07	0.75	0.32
12	Robust	6	1.24	0.72	0.52
13	Azure	6	1.24	0.98	0.26
14	Excel	6	1.33	1.04	0.29
15	Stark	2	1.42	1.04	0.38
16	Bowman	2	1.42	1.13	0.29
17	Morex	6	1.48	0.75	0.73
18	Crystal	2	1.49	0.88	0.61
19	Robust	6	1.53	0.33	1.20
20	Hazen	6	1.56	0.98	0.58
21	Harrington	2	1.75	1.12	0.63
22	Bowman	2	1.78	0.84	0.94
23	Gallatin	2	1.82	0.88	0.94
24	Robust	6	1.87	1.29	0.58
25	Robust	6	2.56	1.63	0.93
Mean		1.14	0.69	0.45	
Std. deviation		0.63	0.41	0.32	

^aSamples were provided by the North Dakota Barley Council, Busch Agricultural Resources, Inc., and NDSU's Department of Crop and Weed Sciences.

SOURCE: Samples were graded by the Canadian Grain Commission and FGIS.

TABLE 10. PAIRED-COMPARISON T-TEST OF THE DIFFERENCE OF THE AMOUNT OF DOCKAGE REPORTED UNDER THE CANADIAN AND U.S. SYSTEMS

Number	Mean	Std. Error	Min.	Max.	T	Prob. T
25	0.45	0.06	0.04	1.20	7.02	0.0001

Malting involves a germination process. A high barley germination level is desired because barley cannot be malted if it does not germinate. Minimum germination rates are usually 95% or greater. Kernel blight can produce a slow and uneven germination, thereby reducing malt extract, and may affect beer taste. Barley color also varies across shipments, and a bright uniform color is desirable. Stained and weathered barley adversely affects the malting process.⁸

Observed Quality Characteristics

This section contains an analysis of data on barley quality at different points in the marketing system. Three sources of data are used to depict barley dockage levels at different points in the marketing system. The first reflects barley quality at the point of production, i.e., data from samples collected at the primary elevator level. The second reflects samples within the U.S. marketing system. The third is based on export samples. Data from each are described first, and then comparisons are made across different points in the marketing system.

Midwest Crop Production Quality

The NDSU Department of Cereal Science and Food Technology annually collects data for the entire state of North Dakota and the major barley production regions of Minnesota and South Dakota. Samples are collected shortly after harvest from farms and elevators. Composite dockage levels were reported for the first year in 1992. Reported composite dockage levels were 1.7% in Minnesota, 2.2% in North Dakota, and 3.8% in South Dakota; the production adjusted dockage level was 2.2% for the three-state average.⁹

This survey also reports plump, thins, test weight, protein, and kernel size. Barley samples are sifted over three screens. The top screen (screen 1) is a 7/64 x 3/4 slotted-hole sieve, the middle screen (screen 2) is a 6/64 x 3/4 slotted-hole sieve, and the bottom screen (screen 3) is a 5/64 x 3/4 slotted-hole sieve. Barley that

⁸Lovas provides a detailed discussion of the impacts of barley quality on the malting and brewing process.

⁹For comparison, 85% of the barley had dockage levels in 1989 of less than 0.5%. Similar data have not been reported in other years.

remains on top of screens 1 and 2 is plump barley. Six-rowed barley that goes through screen 3 is thin barley.

Results from the 1991/92 and 1992/93 crop years were combined, and Table 11 gives the mean, standard deviation, and minimum and maximum for 6-rowed malting varieties. Correlation of the data indicates that plump barley (screens 1 and 2) is significantly and positively related to test weight and significantly and negatively related to protein (Table 12). Thus, high plumpness is associated with low levels of thins and protein and high test weight.

TABLE 11. MEAN VALUES OF SELECTED GRADE FACTOR CHARACTERISTICS IN SIX-ROWED MALTING VARIETIES IN MIDWEST BARLEY PRODUCTION REGION, CROP YEARS 1991/92 AND 1992/93*

	Mean	Std. Dev.	Min.	Max.
Screen 1	18.79	10.51	1.00	63.70
Screen 2	55.17	8.40	4.02	72.40
Screen 3	21.58	10.56	2.90	59.80
Plump	74.08	13.89	15.20	97.10
Thins	4.35	3.96	0.00	33.50
Test wt.	45.91	2.95	30.00	54.40
Protein	12.62	1.30	7.30	16.90

*States include Minnesota, North Dakota, and South Dakota.

SOURCE: Schwartz et al.

TABLE 12. CORRELATION OF SELECTED GRADE FACTOR CHARACTERISTICS IN SIX-ROWED MALTING VARIETIES IN THE MIDWEST BARLEY PRODUCTION REGION FOR CROP YEARS 1991/92 AND 1992/93*

	Screen 1	Screen 2	Screen 3	Plump	Thins	Test Weight	Prot.
Screen 1	1.00	.10*	-.85*	.80*	-.56*	.39*	-.23*
Screen 2		1.00	-.54*	.63*	-.75*	.48*	-.18*
Screen 3			1.00	-.98*	.79*	-.56*	.29*
Plump				1.00	-.88*	.59*	-.31*
Thins					1.00	-.58*	.29*
Test wt.						1.00	-.14
Protein							1.00

*States include Minnesota, North Dakota, and South Dakota.

*Indicates significant at the 10% level.

SOURCE: Schwartz et al.

Regional Quality in the Marketing System

Data contained in the Grain Inspection Monitoring System (GIMS) can be used to infer dockage levels of grains in the market system. GIMS is an FGIS data base comprised of submitted samples, samples for reinspection, and FGIS samples taken to ensure consistency across field offices. The specific origin and whether the barley was cleaned or blended is unknown.

In this study, the GIMS data were used to determine average dockage levels by region. In addition, correlations of dockage with other quality factors were derived. Data used in this analysis were from June 1986 to January 1993. The GIMS data used in this study were refined as follows:

1. All samples at export points were deleted because origin of this barley was unknown.
2. To extract as much information as possible about dockage levels without redundancies, observations were retained if dockage was reported but not contained in a concurrent observation.¹⁰

Observation from states in three geographical regions were specified and reported as:

Midwest: Minnesota, North Dakota, and South Dakota
 Mountain: Colorado, Idaho, Montana, and Wyoming
 Pacific: California, Oregon, and Washington

The predominant barley class for each region was analyzed:

Midwest: 6-rowed barley
 Mountain: 2-rowed and 6-rowed barley
 Pacific: 6-rowed barley

The average dockage level in the GIMS data in the time period was

Midwest 6-rowed:	0.96%
Mountain 6-rowed:	0.84%
Mountain 2-rowed:	0.87%
Pacific 6-rowed:	1.18%

Average dockage levels through time for these three regions are shown in Figure 13. Dockage levels in the Midwest and Pacific states have decreased since the mid-1980s.

Mean values for selected grade factors from the GIMS data are presented in Table 13. The average dockage for 6-rowed barley in the Pacific region is higher than barley in the other two regions, possibly because most of the barley in the Pacific region is of feed varieties that are not regularly cleaned before marketing. Foreign

¹⁰The GIMS data contain three categories of observation: 1) the original sample and grade, 2) supervision or appeal grade, and 3) Board of Appeals for FGIS quality assurance. Some of these observations result in redundancies, which were deleted from the sample.

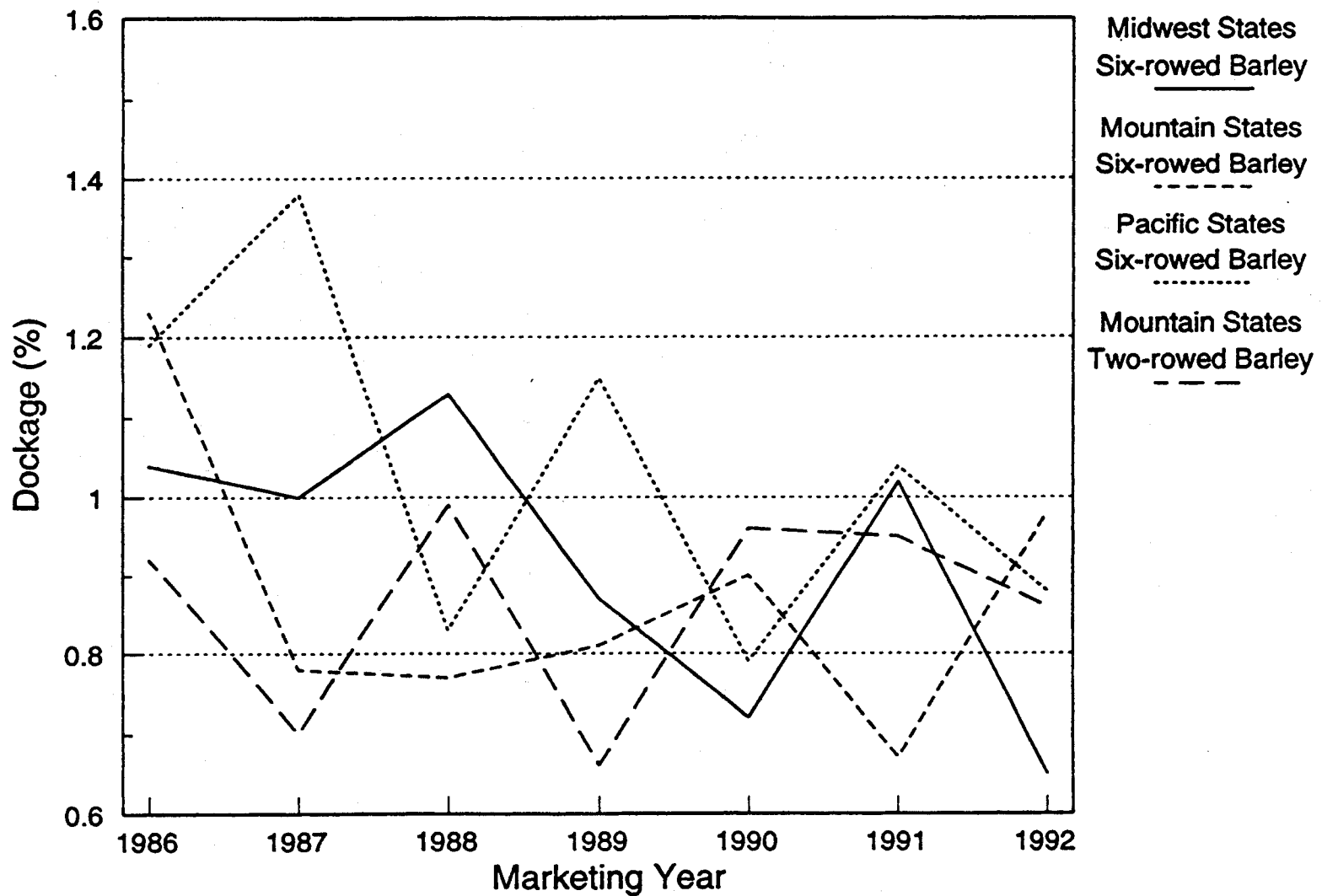


Figure 13. Regional Dockage Levels.

Source: USDA(H).

TABLE 13. MEAN VALUES OF SELECTED GRADE FACTOR CHARACTERISTICS OF BARLEY AT DIFFERENT POINTS IN THE U.S. MARKET SYSTEM^a

	Midwest ^b Six-rowed	Mountain ^c Two-rowed	Six-rowed	Pacific ^d Six-rowed
Dockage	0.96	0.87	0.84	1.18
Test weight	48.65	50.28	47.55	47.79
Foreign material	1.57	3.47	4.15	1.44
Sound barley	97.19	93.55	96.92	95.69
Broken kernels	0.70	1.11	2.58	1.16
Thins	4.51	10.19	7.73	6.41
Shrunken and broken	5.59	3.52	4.18	4.68
Total damage	4.67	3.65	2.62	1.70

^aDomestic inspections from June 1986 through January 1993.

^bStates include Minnesota, North Dakota, and South Dakota.

^cStates include Colorado, Idaho, Montana, and Wyoming.

^dStates include California, Oregon, and Washington.

SOURCE: USDA(H).

material levels, broken kernels, and thins are less than those in the Mountain region. However, the Midwest region has higher shrunken and broken kernels and total damaged kernels than the other two regions.

Correlation coefficients of dockage with these selected grade factors indicate that thins are significantly correlated with dockage for barley grown in all three barley production regions (Table 14). Correlations were positive between dockage and thins, indicating that low dockage levels are associated with low thin levels. The coefficient is the largest in the Midwest states. A larger percentage of the barley is cleaned in the Midwest than in other regions, which may account for this difference. When cleaning to remove dockage, some thin kernels are removed also.

In the Midwest region, dockage in 6-rowed barley is significantly correlated with test weight (negative); foreign material (positive); sound barley (negative); and thins and total damage (both positive). Barley with lower dockage is higher in test weight and percent of sound barley and lower in foreign material, thins, and total damage. Similar relationships exist in some other regions, but are less strong statistically.

TABLE 14. CORRELATION OF SELECTED GRADE FACTOR CHARACTERISTICS WITH DOCKAGE IN BARLEY AT DIFFERENT POINTS IN THE U.S. MARKET SYSTEM^a

	Midwest ^b Six-rowed	Mountain ^c Two-rowed	Six-rowed	Pacific ^d Six-rowed
Test weight	-.25*	-.05	-.11*	+.12*
Foreign material	+.52*	-.13	-.02	+.07
Sound barley	-.17*	+.07	+.00	+.07*
Broken kernels	+.41	+.26	-.14	+.26*
Thins	+.33*	+.17*	+.11*	+.16*
Shrunken and broken	-.01	+.10*	+.04	+.45
Total damage	+.15*	-.05	+.05	+.07

^aDomestic inspections from June 1986 through January 1993.

^bStates include Minnesota, North Dakota, and South Dakota.

^cStates include Colorado, Idaho, Montana, and Wyoming.

^dStates include California, Oregon, and Washington.

*Indicates significant at the 10% level.

SOURCE: USDA(H).

Export Quality

Barley data for all samples exported from the United States are reported in the Export Grain Inspection System (EGIS). For this analysis, all barley exports from the United States between October 1985 and December 1992 were included. The following manipulations were made to the data:

1. All destinations with less than 10 shipments over the time period and all those transited through Canada were combined into "other."
2. West and East Gulf ports were combined.
3. Interior shipments to Mexico were deleted because grade data were not reported on these samples.

Results from these data are shown in Tables 15 to 18. Dockage levels (as opposed to certificated levels) in export shipments range from 0.28% to 3.36% throughout this period, with an average of 1.37% (Table 15). Actual dockage levels have not changed or decreased.¹¹

¹¹This is in contrast to wheat, which had a noticeable reduction in average dockage levels following May 1987, when the procedures for reporting dockage were changed. See Wilson, Scherping, Johnson, and Cobia.

TABLE 15. MEAN EXPORT DOCKAGE LEVELS FOR BARLEY:
BY COMMODITY YEAR

Commodity Year	Mean	St. Deviation	Minimum	Maximum
1985	1.22	.72	.50	2.95
1986	1.55	.53	.63	3.36
1987	1.37	.52	.50	2.83
1988	1.48	.50	.45	3.14
1989	1.40	.54	.30	3.00
1990	1.20	.38	.28	1.91
1991	1.38	.48	.32	2.45
1992	1.32	.48	.41	2.72
Total sample	1.37	.50	.28	3.36

SOURCE: USDA(I).

TABLE 16. MEAN DOCKAGE LEVELS FOR BARLEY:
BY IMPORTING COUNTRY (1985-1992)

Importing Country	N	Mean	St. Deviation
Japan	26	0.98	.35
Saudi Arabia	220	0.92	.56
Jordan	27	1.04	.82
Tunisia	23	0.77	.75
Israel	67	1.06	.75
Other	73	1.19	.78
Cyprus	23	1.34	.82
Algeria	72	1.31	.69
Poland	21	1.14	.99
Romania	14	2.07	.64
Total sample	757	1.37	.50

SOURCE: USDA(I).

TABLE 17. MEAN EXPORT DOCKAGE LEVELS OF BARLEY: SELECTED EFFECTS
(1985-1992)

<u>Class Effect</u>		<u>Grade Effect</u>		<u>Region Effect</u>	
Class	Dockage	Grade	Dockage	Export Region	Dockage
Barley	1.34	1	1.38	East Coast	1.00
6-rowed barley	1.85	2	1.36	Gulf	1.68
		3	1.51	Lakes	1.52
				West Coast	1.04
Total sample					1.37

SOURCE: USDA(I).

TABLE 18. CORRELATION OF DOCKAGE
LEVELS AND OTHER GRADE FACTORS

Factor	Total Sample
Test weight	-.30*
Moisture	.45*
Damaged kernels	.17*
Foreign material	.22*
Sound barley	-.28*
Thin barley	.37*
Brokens	-.02
Shrunken and broken kernels	-.00
Heat damaged kernels	.26*

*Differs significantly from zero at the 10% level.

SOURCE: USDA(I).

Mean dockage levels for individual importing countries are shown in Table 16--ranked from lowest to highest.¹² These range from a low of 0.98% for Japan to 2.07% for Romania. The correlation between the mean dockage level and its standard deviation appears to be positive. Specifically, countries receiving higher (lower) dockage levels also tend to have greater (less) variability in the level of dockage (i.e., standard deviation). Apparently, procurement strategies aimed at reducing the dockage level through contract specifications (as implied in the lower-than-average levels in Japan, Saudi Arabia, and Jordan) have the effect of reducing variability in this particular quality factor.

Mean dockage levels in the total sample were calculated for selected effects (Table 17). The mean dockage level is greater for the class 6-rowed barley than for barley. Dockage is greater for Grade 3 than for Grades 1 and 2. The Lakes and Gulf ports tend to have greater dockage levels than either the East or West Coast ports. Correlations between dockage levels and other grade factors are shown in Table 18 and are consistent with those presented from the GIMS data.

Comparisons

These three data sets compare dockage at different points in the U.S. barley marketing system. The reduction in dockage level between the regional production data and that in GIMS indicates approximately the amount of dockage removed in the marketing system (Table 19 for 1992 and Figure 14 from 1985 to 1992). These differences indicate an estimate of the amount of dockage, which is removed between the production level and the time that it is marketed within the domestic marketing system. Results indicate 1) a significant reduction in the amount of dockage between these two points in the marketing system and 2) an increasing amount of dockage is being removed within the marketing system.

TABLE 19. DOCKAGE LEVELS IN BARLEY IN MINNESOTA, NORTH DAKOTA, AND SOUTH DAKOTA, 1992 CROP

State	Dockage Levels (%)			
	Farm Level		Market Level ^a	
	6-rowed	2-rowed	6-rowed	2-rowed
Minnesota	1.7		1.02	
North Dakota	2.2	5.0	0.54	0.53
South Dakota	3.8		0.68	
Three-state average	2.2 ^b		0.65	

^aBased on Grain Inspection Monitoring System (GIMS) data for June 1992 through January 1993.

^bProduction adjusted average.

¹²"N" in this table indicates the number of shipments during this period. The large number reported to "other" includes those shipped through Canada.

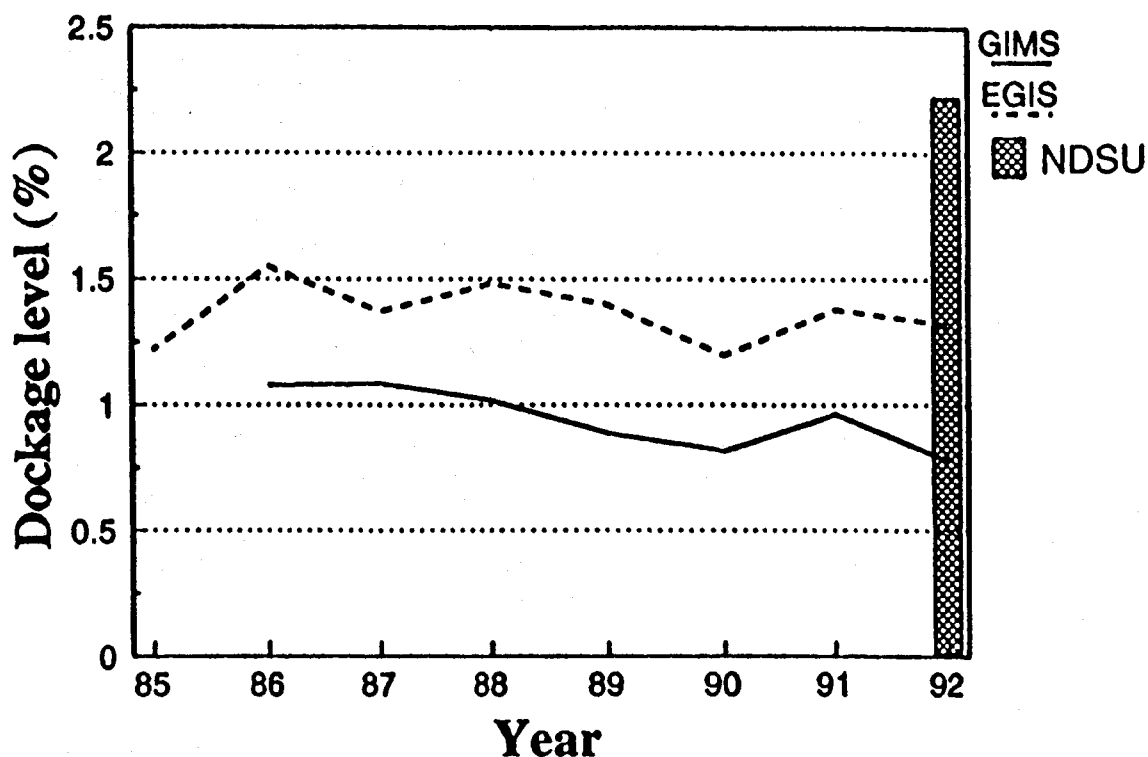


Figure 14. Dockage Levels in the U.S. Marketing System.

In contrast, the amount of dockage in export shipments is substantially greater than that reflected in GIMS. In addition, dockage in export shipments has not decreased through time as it has within the domestic market system. Apparently, either marketing innovations (e.g., contract specifications) that have been occurring domestically have not been adopted in the export marketing system or market conditions do not warrant removal of dockage for exported grain.

Merchandising, Handling, and Cleaning Practices

This section is based on two surveys--the National Grain and Feed Association survey and a North Dakota State University survey of elevator managers. The purpose of these surveys was to identify and document merchandising, handling, and cleaning practices in the U.S. barley industry.

The National Grain and Feed Association (NGFA) in 1991 conducted a *Survey of Commercial Elevator Grain Cleaning Facilities* (Survey A in Appendix A) of country, terminal, and export elevators that handled wheat, corn, soybeans, sorghum, and barley in the United States. Elevators were categorized by type (country, terminal, export) and geographical location (Central, Midwest, Mountain, or Pacific).

In January 1992, the Department of Agricultural Economics at NDSU conducted a *Survey of Country Elevator Managers on the Capabilities of Removing Dockage from Barley* (Survey B in Appendix A). This survey was sent to elevator managers in major barley-producing regions of Minnesota, North Dakota, and South Dakota. Elevators were categorized also according to the predominant barley class handled. Malting barley represented over 50% of the barley sold for 44 elevators, which were classified as "malting barley elevators." Feed barley represented 50% or more of the barley sold for 60 elevators, which were classified as "feed barley elevators."

Results will be presented as follows. First, characteristics of the respondents are discussed. Second, merchandising practices are described, including purchasing and use of premiums and discounts. Third, all the results related to barley cleaning are presented, including ranking factors that affect cleaning decisions, cleaning equipment, and costs. All the results are presented in a comparison technical report which is available from the authors.

Respondent Characteristics

The NGFA survey contains 180 usable responses. They were predominantly from country elevators, located primarily in the Midwest. However, responses to some questions on the NGFA survey were substantially less than the total number of respondents. The NDSU survey had 104 usable responses, all country elevators located in the Midwest. Of these elevators, 44 handled volume that was comprised of more than 50% malting varieties.

The dominant load-out capacity in the Midwest was between 7 and 26 cars per day, and the average total storage capacity was 540,825 bushels. In the Midwest, 20% of the responding elevators had a separate facility to handle barley; and, of those specializing in malting barley, 34% had a dedicated facility for this grain.

The majority of country elevators in the Midwest and Mountain states had cleaners, 97% and 63%, respectively. Country elevators in other states had cleaning equipment. Cleaning capacity averaged 3,461 bu/hr in Midwest country elevators, more than Pacific and Mountain country elevators and terminal and export elevators. This suggests that a common marketing practice is for cleaning to occur at country elevators, particularly in dominant barley-producing regions.

The responding country elevators bought 97% of their barley from farmers. Terminal elevators bought 55% of their barley from farmers and the balance from other merchants. The NDSU survey indicated that 61% of the barley handled at Midwest country elevators was 6-rowed malting varieties and 4% was 2-rowed malting varieties. In contrast, of the barley they sold, 40% was 6-rowed malting and 1% was 2-rowed malting. Thus, a significant percentage of what is produced/grown as malting barley is not sold for malting purposes.

Table 20 shows the average of the physical quality characteristics of barley that country elevators purchased for each region. The quantity of both dockage and foreign material is highest at Midwest locations, followed by Mountain and Pacific regions. These dockage levels are less than dockage levels at country elevator locations. The level of thins is greatest in Mountain regions, followed by the Midwest and Pacific.

TABLE 20. AVERAGE PHYSICAL QUALITY
CHARACTERISTICS ON INBOUND BARLEY

Elevator Group	Dockage	Foreign Material	Thins
Midwest	1.47	1.16	7.77
Mountain	1.18	0.89	12.00
Pacific	0.56	0.22	6.8
Terminal	0.83	1	7.83

SOURCE: Appendix Tables DA6 to DA8.

Merchandising Practices

Buyers and sellers generally treat dockage in one of two ways:

- Buy (sell) barley on gross weight basis
- Buy (sell) barley on weight-deductible basis

Gross weight basis means that the total weight of barley and dockage is bought (sold) as barley. Weight-deductible (sometimes referred to as net weight) means the dockage percentage is subtracted from the total weight (barley plus dockage), and the value of the transaction is based only on the barley weight.

Midwest country elevators have a greater tendency to use weight deductions than Mountain or Pacific country elevators when buying malting barley. In the Midwest, 86% of the responding elevators used the weight-deduction method, compared to 69% and 43% in the Pacific and Mountain regions, respectively. The one export and one terminal elevator that responded to this question bought malting barley on a weight-deductible basis. Pacific country elevators apply weight deduction more often than either Midwest and Mountain country elevators when buying feed barley. One export and three terminal elevators bought feed barley on a weight-deductible basis. The NDSU survey indicated that 86% of the elevators specializing in malting barley used net weight (i.e., weight deductible), compared to 48% of

the elevators that specialize in feed barley. The average weight deductible percent is lower in the Midwest than Mountain and Pacific elevators.

Grain buyers use premiums and discounts to induce desired quality characteristics and to reflect their valuation of these characteristics. Country and terminal elevators listed thin barley and "other" factors as the primary discount in barley received. Factors in the "other" category include discounts for protein and test weight for Midwest country elevators and test weight for terminal and Pacific country elevators.

Elevators considered other grains and thin barley more heavily as a discount factor when buying malting barley than when buying feed barley. However, "other" factors were the primary source of discount when buying feed and malting barley. When buying malting barley, elevators listed protein first; and shrunken and broken and test weight tied for the second most common discount factor listed in the "other" category. When buying feed barley, elevators ranked test weight and protein the first and second most common factors, respectively, in the "other" category.

Only three elevators in the Midwest and one in the Pacific regions received discounts for dockage levels above specified quantities; and only one received a premium for dockage less than specified levels. This is in contrast to total responses of 88 and 45 in these two regions, respectively, and 19 in the Mountain states. Similar responses were received in the NDSU survey. These results suggest that premiums and discounts for dockage are used infrequently and that dockage is more often treated simply as a weight deduction.

Discounts are more common for thins and other grade factors. However, in all cases, Midwest elevators use these discount schedules more often. Average discounts applied for these factors for the Midwest elevators are shown in Table 21.¹³ Discounts for thins increase throughout the range, beginning at 6%. For levels of thins between 6% and 12%, the discount increases at an increasing rate, providing an important penalty for samples with high levels of thins. Discounts for foreign material are greater for malting than for feed barley. However, the foreign material discount in feed barley does not begin until levels of 1.5%. The discount increases radically with increases in foreign material, indicating an increasingly severe penalty for foreign material at higher levels. These results are similar to those in the NDSU survey.

Cleaning Practices and Costs

Reasons to Clean and Frequency of Cleaning. Country elevators located in the Midwest cleaned 37% of the barley handled, a larger percentage than the elevators located in other regions. Country

¹³These are the averages for all respondents using nonzero values.

TABLE 21. DISCOUNTS MIDWEST COUNTRY ELEVATORS USE FOR
SELECTED CHARACTERISTICS

Thins		Foreign Material		
Percent	Malting Discount ¢/bu	Percent	Malting Discount ¢/bu	Feed Discount ¢/bu
5.0	2.5	0.5	1.1	0.0
6.0	2.2	1.0	2.4	0.0
8.0	4.3	1.5	2.7	2.4
10.0	7.7	2.0	4.3	2.3
12.0	10.0	2.5	5.8	3.3
14.0	15.1	>3.0	7.7	5.1
>15.0	17.9			

SOURCE: Tables DA15 to DA17.

elevators located in the Pacific region cleaned an average of 28% and those in the Mountain region less than 10%. Additional information was asked in the NDSU survey. Of the total barley shipments, 38% were cleaned and 11% were graded (sized). Elevators specializing in malting barley cleaned more frequently (45% cleaned and 17% sized) than did elevators specializing in feed barley (32% cleaned).

Cleaning decisions involve many variables, which change from location, time, and type of elevator. Of the Mountain and Pacific country elevators, only one and three managers, respectively, in the NGFA survey explained why cleaning was done. Midwest country elevators clean barley to reduce insect problems, meet contract specifications, and avoid discounts. The difference between feed elevators and malting elevators was significant.

The initial dockage level was the most important reason in the NDSU survey for deciding whether to clean. Meeting contract specifications and transportation savings were the second and third most important reasons for cleaning.

The NGFA survey also asked elevator managers what factors are important when deciding not to clean barley. The most important reasons were insufficient premiums for clean grain and equipment investment was too costly for Midwest, Mountain, and Pacific country elevators.

Cleaner Type/Age. The NDSU survey sought specific information on age, purchase, and installation costs of elevators' dominant cleaner and the different types of cleaners. The years in which cleaners were

purchased ranged from 1943 to 1991, at an original cost ranging from \$1,200 to \$60,000. Installation costs ranged from \$500 to \$60,000. The dominant type of cleaner was a "disk/cylinder," while the "rotary system" was least common. Purchase and installation costs for a disk/cylinder system were less than any of the other types, but they were also older and smaller.

Barley Losses From Cleaning. An important element of cleaning costs is the loss of plump barley in the cleaning process. Respondents indicated the average plump barley loss increased from 1.56% to 4.29% when the ending dockage was decreased from 1% to 0.1%. Loss of plump barley was greater from the disk/cylinder cleaner than from other types of cleaners.

Cleaning Capacity Ratings and Costs. Both surveys contained questions about cleaning capacities and costs. Since those in the NDSU survey were more detailed and the response was greatest, they are used for interpretation. Anomalies will be identified if they vary substantially from the NGFA survey.

Cleaning cost depends on the level of ending dockage to which the barley is cleaned because the working capacity decreases when cleaning to lower ending dockage levels. Also, barley loss increases when cleaning to lower dockage levels. In general, working capacity decreases as the ending dockage level is reduced.

The average cleaning cost for all cleaners increases from 3.1¢/bu with an ending dockage level of 1.0% to 7.5¢/bu for an ending dockage level of 0.1%. For the disk/cylinder, which was the most common technology, the average cleaning cost increased from 3.6¢/bu to 8.2¢/bu when going from 1.0 to 0.1% dockage. The NGFA survey reported average cleaning costs of 7¢/bu in the Midwest and Pacific regions and 11.5¢/bu in the Mountain region.

When elevators allocated cleaning costs among six categories of operating costs, the allocations were similar across cleaning technologies. The weighted average is reported here. The three dominant categories of costs were labor (30%), repairs (25%), and energy (22%). The costs of additional elevation and loss of plump barley comprised 15% and 5%, respectively, of the operating costs of cleaning. Gravity and flat screens were the most energy efficient, whereas the disk cylinder required the least labor.¹⁴

Value and Use of Screening. The screening price is an important factor in deciding to clean because it represents the value of the cleaning by-product, screening. The price of screening in both surveys ranged from \$27/ton in the Midwest to \$55 in the Mountain region to \$82 in the Pacific region. The average price of screening in the NDSU survey was between \$18 to \$19/ton between 1989 to 1991. However, elevators specializing in malting barley received about

¹⁴In addition, similar questions were asked about grader/sizer equipment and costs (Tables DB17 to DB20).

\$5/ton less for screening than did other barley elevators. Midwest country elevators used screening for feed and shipped an average of 46 miles to the feed market. Mountain state elevators tended to use the screening more in their own feed mill, but sales to the feed market still dominated.

Expansion of Cleaning Capacity and Costs. Each survey asked elevators about their ability to expand capacity. The NGFA survey indicated that, except for the terminal elevators, less than one-half of the elevators could install grain cleaners. This ranged from 23% of elevators in the Pacific region that could install cleaners to 47% in the Mountain region. The majority of the elevators indicated that installing additional cleaners would cost less than \$100,000.

The NDSU survey asked what changes would be necessary if all barley had to be shipped at less than 0.5% dockage. For "all" the elevators, 30% would have to install additional equipment with major modifications to their facility; 55% would make no equipment changes, but 63% of these would require additional elevation or handling. About one-half (51.3%) of the elevators would use premiums and discounts if all barley had to be shipped at 0.5% dockage. These results suggest that cleaning capacity at the country elevator level is adequate. However, stricter regulations would force more cleaning in the post-receipt timeframe, thereby necessitating additional handling.

Malt Industry Practices

Maltsters are more concerned about quality characteristics other than dockage. All barley is cleaned and, in some cases, sized before it is malted. Thus, dockage levels do not concern maltsters; also, barley can be bought on a weight-deductible basis. However, some malting companies do not deduct for the first 1% dockage. This practice encourages producers not to skin barley during harvesting and elevator managers not to overclean, which can lead to skinning.

Economic-engineering Cost Estimates

Cleaning cost estimates are based on surveys of selected equipment manufacturers and country elevators. Engineers of equipment manufacturers provided original equipment and installation costs and operating characteristics. Elevator managers provided ranges of operating characteristics and some efficiency estimates. Impacts of barley loss and operating efficiency are reported.

Cleaning Technology

Screen, aspiration, and disk/cylinder cleaners are the three major technologies used to clean barley. Firms located in the major grain producing areas manufacture these cleaners. A few manufacturers produce a full line of cleaners, while others only manufacture one type.

Cleaning barley differs from that of other common grains. It does not flow as smoothly because of its husks. Handling increases skinning (loss of hulls), but breakage is not as much of a problem as it is for corn. Two-row barley is generally easier to clean than 6-row barley because kernels of 2-row barley are larger and more uniform.

Screen

Screen cleaners use a combination of screens to separate material. Scalping, normally the first phase, leaves large undesirable pieces on top. Smaller sized screens allow small undesirable material (fines) to pass through. Rated capacity for removing fines, measured by screen area, is less than for scalping because the particles removed are generally similar in size to the grain. Screen cleaners are generally classified by the way grain is moved across the screen: vibrating, drag, rotary, and gravity.

Vibrating or reciprocating screen cleaners consist of inclined screens, vibrating at 600 to 1,400 strokes per minute to provide a shaking motion. Gyrator cleaners use the same concept, but the strokes are longer and lower (200 to 300) (Quinn). Often, aspiration is used in conjunction with the screening action.

Drag-type cleaners involve a moving chain that drags the grain across the screen. This little-used technology is most useful when available head space is narrow. Revolving rotary screens consist of a revolving drum with two sets of perforated plates or screens. Grain is fed into the center of the drum. Grain and fines fall through the internal screen, leaving large undesirable material on the internal screen. Small undesirable material falls through the external screen, while desired grain is conveyed to either end of the external drum. This technology, used most often at the farm, has found acceptance at country elevators.

Gravity screens use a drop in elevation to feed grain across screens set at an angle. These screens are less efficient than other types, but they are less expensive because they have no moving parts. They are preferred for large volume when cleaning objectives are moderate.

Purchase, installation, and operating costs of vibrating screens generally exceed those of gravity machines, but dockage removal is more precise because of multiple-screen decks and the mechanical motion of the machine.

Aspiration

Aspiration, or increased air flow cleaners, separate low-density material (chaff and insects) from higher density material (grain). This is one of the least expensive methods of removing bulky dockage. High air flow rates can result in barley loss, which disk/cylinder

cleaners can reclaim. Aspiration is often used in conjunction with other techniques and is often used as part of the dust collection system.

Disk/Cylinder

A cylinder cleaner is a horizontal rotating cylinder with small indentations in the metal. Grain is fed into the middle of the cylinder. Smaller material falls into the indentations and is lifted as the cylinder revolves. The material drops as it reaches the top. The larger material drops out first. Adjustments can be made so that the threshold length can vary according to the type of grain and type of material being removed.

Disk cleaners use multiple disks whose surfaces contain indentations similar to those in cylinder cleaners. The disks are attached to a rotating shaft. Smaller material is lifted to a point where it is separated from the grain. Disk cleaners can be adjusted more easily than can cylinder cleaners. Aspiration and scalping usually are used ahead of the disk/cylinder cleaner. This technology is generally most effective for removing the largest percentage of dockage, but the investment and operating costs are relatively high and the capacity is low.

Selection of Illustrative Cleaners

A survey (Appendix B) sent to 12 grain cleaner manufacturers to collect information on the cost and operating characteristics when used for cleaning barley. Six manufacturers responded.

The three cleaners selected to illustrate cleaning costs and to provide costs for the decision-making model are of the screen type (Table 22). Cleaner A is a portable rotating screen designed for farm use. Cleaners B and C are intended for use by country elevators. Cleaner B (reciprocating air screen) has a built-in dust removal system, while Cleaner C does not. Cleaner C is a rotating screen intended for high-speed cleaning.

Analysis of cleaning at the export level was not made because less than 8% of the barley exported is malting quality. Dockage removal in feed barley for export is relatively unimportant; feed barley seldom is cleaned.

Derivation of Costs

Economic-engineering costs for cleaning dockage from barley are derived from information obtained from surveys of cleaner manufacturers and country elevators (Appendix C) and interviews with elevator managers, manufacturer representatives, and agricultural engineers. Screen cleaners were used for two reasons. First, these were the only cleaner types represented in our survey results.

TABLE 22. SPECIFICATIONS AND ESTIMATED OPERATING CHARACTERISTICS OF
SELECTED GRAIN CLEANERS WHEN CLEANING BARLEY, 1992

Item	Cleaner Designation/Technology		
	A - Rotating Air Screen	B - Reciprocating Air Screen	C - Rotating Screen
Rated barley cleaning capacity (bu/hr)	1,500	2,200	7,200
Expected useful life			
Years	7.0	25	25
Cleaner (mil/bu)	7.5	175	200
Screens (mil/bu)	1.5	10	10
Dust collection	yes	yes	no
Original investment			
Cleaner (\$)	8,302	49,000 ^a	85,000
Installation (\$)	portable	30,000	50,000
Total cost/bu rated capacity (\$)	5.53	35.91	18.75
Operating requirements			
Horsepower	7.6	23.5	10.0
Labor (min/hr)	12	12 ^b	12 ^b
Maintenance (\$/8 hr)	3.96	3.75	3.10
Replacing screens			
Screens (unframed) (\$)	975	1,070	3,680
Labor to change screen (hr)	2.0	7.5	4.0

^aIncludes dust collection system.

^bDerived from survey of elevator managers.

SOURCE: Equipment manufacturers survey with noted exceptions (Appendix E).

Second, the interviews indicated that this was the predominant cleaner type now being installed. Characteristics of the three cleaners selected to illustrate cleaning costs are shown in Table 22. Costs, calculated on a per hour basis, were converted to a per bushel basis.

The impact of initial and ending dockage levels on working capacity and barley loss is analyzed. Costs are classified as fixed (indirect) or variable (direct). Benefits from cleaning, such as sale of screenings, are introduced into the analysis in the "Budget Analysis of Cleaning Decisions" section on page 55.

Working Capacity and Efficiency

Working capacity is the actual cleaning capacity of a cleaner operating under a given set of conditions. Specifications for grain cleaners generally list rated or theoretical cleaning capacity. Most cleaners can operate at or near rated capacity when the amount of material to be removed is small and the specified ending dockage level is relatively high. However, intensive cleaning takes more time (hence more electricity, labor, and repairs). Thus, working capacity is the capacity in bushels per hour at which the cleaner operates in normal operating conditions, which are typically more restrictive.

Working capacity is related to initial and ending dockage levels in this study. Equipment manufacturer engineers provided the percent of rated capacity at which the cleaner could operate, given initial and ending dockage levels. All surveys indicated a change in working capacity associated with changes in initial and ending dockage levels. Cleaning capacity decreases as ending dockage level decreases and/or the initial dockage increases (Table 23). The reduction in cleaning capacity (bu/hr) affects the amount of grain cleaned and, thus, cleaning cost.

TABLE 23. PERCENT OF RATED
CAPACITY WHEN CLEANING BARLEY
FROM AN INITIAL TO AN ENDING
DOCKAGE LEVEL FOR SELECTED GRAIN
CLEANERS, 1992

Cleaning Dockage Level		Rated Capacity of Cleaner:		
From	To	A	B	C
----- percent -----				
Initial	Ending			
4.0	1.0	76	85	50
	0.8	72	80	40
	0.5	65	70	35
	0.2	53	50	30
2.5	1.0	83	95	70
	0.8	78	90	50
	0.5	72	80	45
	0.2	60	65	40
1.0	0.8	83	100	65
	0.5	77	90	60
	0.2	67	80	50

Working capacity used to calculate costs is derived as

$$\text{Working Capacity} = \text{RC} * \text{PRC}$$

where RC = rated capacity (bu/hr) from Table 22

PRC = percent of rated capacity when cleaning from a specified initial dockage level to a specified ending dockage level from Table 23

The working capacity was used to place all hourly costs on a per bushel basis. Most costs were calculated on a per hour basis. These costs were divided by the working capacity to obtain costs per bushel. When working capacity changes, so does the rate at which cleaning costs are incurred. As working capacity decreases, all per unit costs increase; and cleaning to lower specified ending dockage levels becomes more expensive.

Efficiency

Factors that influence cleaner working capacity are generally the same factors that influence cleaner efficiency. Cleaner efficiency is defined as

$$\text{efficiency}(\%) = 100 \times \frac{\text{amount of material removed}}{\text{amount of material that could be removed}}$$

"Efficiency is not constant. It falls with higher initial levels of undesirable material, with increasing moisture, and with increasing flowrate" (Hurburgh). Some types of dockage are more difficult to remove than others. Near-fit is dockage that is similar in size and shape to barley. The cleaning efficiency for near-fit is lower than for sizes that are smaller than the screen opening (Hurburgh).

To achieve a high cleaning efficiency flow rate, the flow rate (working capacity) can be reduced and/or a larger screen opening can be used. Although a larger screen opening does a better job of fines removal, the loss of acceptable grain is increased (Quinn).

Sizing and Removal of Thins

Thins (defined on page 20) are not a part of dockage and are, therefore, beyond the scope of this report. But, in some instances, thins often are separated along with dockage, depending on screen size, flow rate, and size of thins. One approach used to meet maltster requirements is to size the barley (classify it by width). Objectives are to remove thins and to segregate remaining barley to meet protein requirements. Sizing is more severe and, thus, more expensive than cleaning.

Fixed Costs

Fixed (or indirect) costs are incurred, regardless of cleaner operating time. Therefore, average fixed costs decrease as operating time increases (or number of bushels cleaned increases). Fixed costs associated with owning the cleaner include depreciation and opportunity costs of the investment (for equipment and installation).

Depreciation

Depreciation is the loss in value of a long-lived investment associated with the passage of time or use of a long-lived investment assigned to current production. Depreciation was calculated, using a straight-line schedule for 25 years. This period fell in line with the range of estimates from equipment manufacturers. Installed cost varies, depending on equipment and installation costs. Installation varies considerably, depending on modification required on existing plant facilities to accommodate the cleaner. All costs are first calculated on a per hour basis, assuming, in the base case, 700 hours per year. Hourly costs are converted to a bushel basis, using working rates (Table 23) from different per bushel depreciation rates.

Depreciation also could be allocated on use rather than time. Manufacturers estimated the useful life of Cleaners A, B, and C as 7.5, 175, and 200 million bushels (Table 22), respectively. Depreciation is 0.045¢/bu for Cleaner B ($\$79,000/175,000,000$ bu) for rated capacity. This depreciation cost must be increased proportionally by the percentage that rated capacity is reduced, depending on initial and ending dockage levels (Table 23). Depreciation, based on an initial and ending dockage of 2.5% and 0.8%, is 0.06¢/bu. Cleaning to 0.2% doubles depreciation to 0.12¢/bu. These depreciation rates are considerably lower than the equivalent figures of 0.26¢/bu and 0.37¢/bu obtained, using the straight-line method. Cleaning cost tables equivalent to Tables 24 and 25 that include depreciation, based on use rather than time, are given in Appendix C (Tables C1 and C2).

Opportunity Cost of Capital

An opportunity cost was charged against cleaning system ownership and installation cost to account for foregone interest income or interest being paid on borrowed funds. The current long-term loan rate of 6.85% from the St. Paul Bank for Cooperatives was used. One of the major clients of this agency is country elevators. This opportunity cost was charged against one-half of the purchase price and installation cost of the cleaning system. One-half represents the average investment in the cleaning system if the salvage value of the system is zero.

TABLE 24. ESTIMATED BARLEY-CLEANING COSTS (STRAIGHT-LINE DEPRECIATION) FOR A COUNTRY ELEVATOR, CLEANER B (SCREEN), 2,200 BU/HR, INITIAL DOCKAGE LEVEL OF 2.5%, CLEANING FOR 700 HOURS PER YEAR, 1992

Cost Component	Cleaned to Dockage Level:			
	0.8%		0.2%	
	Annual	¢/bu	Annual	¢/bu
Bushels cleaned	1,386,000		1,001,000	
Fixed costs:				
Depreciation	\$ 3,672	0.26	\$ 3,672	0.37
Opportunity	3,144	0.23	3,144	0.31
TOTAL FIXED COSTS	6,816	0.49	6,816	0.68
Variable costs:				
Barley loss ^a	\$50,936	3.68	\$70,070	7.00
Energy	1,006	0.07	1,006	0.10
Labor	1,079	0.08	1,079	0.11
Maintenance	328	0.02	328	0.03
TOTAL VARIABLE COSTS	53,349	3.85	72,483	7.24
TOTAL COSTS	\$60,165	4.34	\$79,299	7.92

^aAssuming 2.1% and 4.0% barley loss when cleaning to 0.8% and 0.2%, respectively.

TABLE 25. BASE TABLE USED TO ILLUSTRATE THE IMPACT OF CHANGES IN EQUIPMENT USE RATE AND BARLEY LOSS ON BARLEY CLEANING COSTS WITH A USE RATE OF 700 HOURS PER YEAR, 1992

Cleaning From To		Assumed Barley Loss	Type of Cleaner ^a		
			A (1.5)	B (2.2)	C (7.2)
----- percent -----			----- ¢/bu -----		
4.0	1.0	1.5	3.1	3.3	3.1
	0.8	2.1	4.1	4.4	4.3
	0.5	2.7	5.2	5.6	5.4
	0.2	4.0	7.6	8.2	7.8
2.5	1.0	1.5	3.0	3.3	3.0
	0.8	2.1	4.1	4.3	4.1
	0.5	2.7	5.2	5.5	5.2
	0.2	4.0	7.6	7.9	7.6
1.0	0.8	2.1	4.1	4.3	4.0
	0.5	2.7	5.2	5.4	5.1
	0.2	4.0	7.5	7.7	7.5

^aRated capacity (1,000 bu/hr) in brackets.

Variable Costs

Major variable (or direct) cost components are energy, labor, maintenance, and barley loss. These costs are directly related or vary directly with hours of cleaner operation or bushels cleaned. Cost per bushel, as with fixed costs, increases proportionately as working capacity is decreased.

Energy

The only energy required is electricity to power electrical motors. Electrical motors on cleaners use 0.746 kw/hp. The weighted average price for North Dakota commercial use of electricity was 7¢/kwh in July 1992 (Energy Information Administration). This weighted average includes a facility charge, a peak demand charge, and quantity discounts.

Labor

Most equipment manufacturers reported that casual inspection was the only routine labor requirement needed to operate a cleaner. However, most country elevator managers frequently inspect their cleaner to see that it is operating properly. They estimated an average of 10 to 15 minutes per hour was devoted to starting, inspecting, and adjusting the cleaner. Labor requirements were assumed to be 12 minutes per hour. The wage rate of \$7.71 per hour was calculated from data provided by the North Dakota Grain Dealers Association 1981 *Employee Compensation Survey of North Dakota Country Elevators* and indexed to the current year, using the Consumer Price Index.

Maintenance

Long-term maintenance costs reflect upkeep from normal wear. This includes replacing disks, cylinders, screens, bearings, and motors. Maintenance costs, obtained from equipment manufacturers, are reported on an 8-hour-per-day basis (Table 22).

Barley Loss

Barley loss is marketable barley inadvertently removed with dockage during the cleaning operation. Little research or industry data exist on this topic. The rationale for incorporating barley loss into the cleaning cost analysis is adapted from Scherping et al. This study reported two lines of thought on the existence of and the change in the level of grain loss as it is cleaned to lower dockage levels.

[One] group thought that the only way to clean wheat down to the 0.1% dockage level was with a disk/cylinder cleaner. This technology can be used independently or in

conjunction with another system; e.g., first, overclean wheat with a different type of cleaner and reclaim the salable wheat from removed dockage with a cylinder/disk cleaner. The second group thought that screen and aspiration cleaners could achieve low levels of dockage with some loss of salable wheat. They disagreed about the economic significance of this loss but agreed that the disk/cylinder cleaners lost the least wheat and the aspiration cleaners lost the most wheat when cleaning to low dockage levels.

The loss factor varies with all the conditions affecting efficiency (Hurburgh). Factors affecting wheat loss include type of dockage to be removed (e.g., near-fit), moisture, flow rate, incoming dockage, and the elevator manager's ability in adjusting the cleaner.

Among the manufacturers surveyed, only the aspiration manufacturer included a percentage for wheat loss. All other manufacturers had no loss of salable wheat in the removed dockage. However, selected elevator managers agreed that wheat loss occurred. The loss increased as the wheat was cleaned to lower dockage levels.

Representatives of a screen cleaner manufacturer indicated in telephone conversations that while some wheat was lost with dockage, the loss could be kept to a minimum by correctly matching screen size to the wheat and dockage. When cleaning to low dockage levels with correct screens, the main loss would be in working capacity (Scherping et al., p. 20).

Barley loss levels used in this report come from the NDSU survey of barley handling elevators (Table 26). These data were interpolated to obtain additional ending dockage levels needed for the cost analysis. These values are educated guesses about plump barley loss to represent a range of conditions. Cleaning cost charged to barley loss at specified ending dockage levels was calculated by

$$BL = WC * PBL$$

where BL = barley loss

WC = working capacity

PBL = percent of barley loss when cleaning

Most elevators in North Dakota sell their screenings. Therefore, the actual value of barley loss is the price difference between screenings and barley. In North Dakota, the average price of screenings in 1991 was \$18.34 per ton, and the average price of all barley was \$1.75 per bushel, which equals \$16.66 per ton or a 0.83¢/lb. difference. These values are included later in the analysis.

TABLE 26. ESTIMATED AND
INTERPOLATED PERCENTAGES OF
PLUMP BARLEY LOSS WHEN
CLEANING TO SPECIFIED ENDING
DOCKAGE LEVELS

Ending Dockage	Survey Average	Interpolated Values
----- percent -----		
1.0	1.56	1.5
0.8	--	2.1
0.5	2.66	2.7
0.2	--	4.0
0.1	4.29	--

Per Bushel Cleaning Costs

Cost components discussed in the preceding section for Cleaner B, as an example, are converted to an annual and per bushel basis in Table 24. This represents the base model used to illustrate cleaning cost components and impacts on costs of variations in barley loss and equipment utilization. Costs in Table 24 were estimated, assuming an initial dockage of 2.5% and ending dockage levels of 0.8% and 0.2%. The lower ending dockage level of 0.2% illustrates the impact on costs of more precise cleaning, assuming the cleaner was operated 100 days per year at 7 hours per day or 700 hours per year.

The 700 hours of cleaning translate into 1,386,000 and 1,001,000 bushels being cleaned per year with an initial dockage of 2.5% and ending dockage levels of 0.8% and 0.2%, respectively. Cleaning costs were 4.3¢/bu and 7.9¢/bu, respectively. The impact of different levels of barley loss and utilization rates on cleaning costs are shown in Tables 25 and 27 to 29 and Figures 15 and 16.

Fixed costs are higher when cleaning to a lower dockage level because they are spread over fewer bushels. The value of barley loss increases because of the assumption that more salable barley is removed as barley is cleaned to a lower dockage level. Energy, labor, and maintenance increase on a per bushel basis because of a decline in working capacity when cleaning to lower dockage levels.

Cleaning costs in Table 25 are positively related to initial dockage level and negatively related to ending dockage level. Cleaning costs rise substantially when cleaning to lower dockage levels (Figure 15). This relationship is due to lower working capacities and increased barley loss when cleaning to lower dockage levels.

TABLE 27. ESTIMATED BARLEY-CLEANING COSTS
WITH A USE RATE OF 700 HOURS PER YEAR
WITH NO BARLEY LOSS, 1992

Cleaning		Assumed Barley Loss	Type of Cleaner ^a		
From	To		A (1.5)	B (2.2)	C (7.2)
----- percent -----			----- ¢/bu -----		
4.0	1.0	0.0	0.4	0.7	0.5
	0.8	0.0	0.5	0.7	0.6
	0.5	0.0	0.5	0.9	0.7
	0.2	0.0	0.6	1.2	0.8
2.5	1.0	0.0	0.4	0.7	0.3
	0.8	0.0	0.4	0.7	0.5
	0.5	0.0	0.5	0.7	0.5
	0.2	0.0	0.6	0.9	0.6
1.0	0.8	0.0	0.4	0.6	0.4
	0.5	0.0	0.4	0.7	0.4
	0.2	0.0	0.5	0.7	0.5

^aRated capacity (1,000 bu/hr) in brackets.

TABLE 28. ESTIMATED BARLEY-CLEANING
COSTS WITH A USE RATE OF 700 HOURS
PER YEAR WITH HIGH LEVELS OF BARLEY
LOSS, 1992

Cleaning		Assumed Barley Loss	Type of Cleaner ^a		
From	To		A (1.5)	B (2.2)	C (7.2)
----- percent -----			----- ¢/bu -----		
4.0	1.0	3.0	5.7	6.0	5.7
	0.8	4.2	7.8	8.1	7.9
	0.5	5.4	10.0	10.3	10.1
	0.2	8.0	14.6	15.2	14.8
2.5	1.0	3.0	5.7	5.9	5.6
	0.8	4.2	7.8	8.0	7.8
	0.5	5.4	9.9	10.2	10.0
	0.2	8.0	14.6	14.9	14.6
1.0	0.8	4.2	7.8	7.9	7.7
	0.5	5.4	9.9	10.1	9.8
	0.2	8.0	14.5	14.7	14.5

^aRated capacity (1,000 bu/hr) in brackets.

TABLE 29. ESTIMATED BARLEY-
CLEANING COSTS FOR CLEANER B,
ASSUMING SPECIFIED USE RATES
WITH NO BARLEY LOSS, 1992

Cleaning		Days/Year ^a		
From	To	50	100	150
percent		¢/bu		
4.0	1.0	1.22	0.70	0.53
	0.8	1.30	0.75	0.56
	0.5	1.49	0.85	0.64
	0.2	2.08	1.19	0.90
2.5	1.0	1.16	0.66	0.50
	0.8	1.16	0.66	0.50
	0.5	1.30	0.75	0.56
	0.2	1.60	0.92	0.69
1.0	0.8	1.04	0.60	0.45
	0.5	1.16	0.66	0.50
	0.2	1.30	0.75	0.56

^aAssumes 7-hour days.

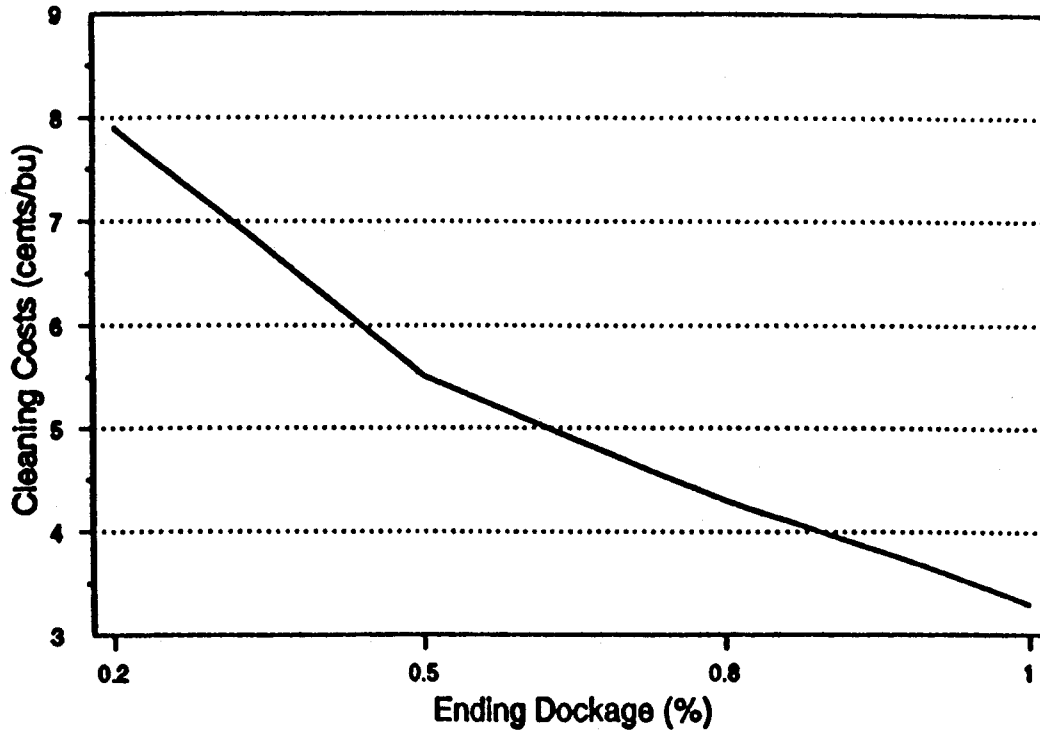


Figure 15. Effects of Ending Dockage Levels on Economic-engineering
Cleaning Costs for Cleaner B With a Beginning Dockage of 2.5%, 1992.
See Table 26 for assumptions and numerical values.

Impacts of Barley Loss

The amount of barley lost with dockage in the cleaning process has the most significant impact on cleaning costs, accounting for 86% to 89% of total costs in the base case (Table 24). This is the most uncertain cost component because little research is available from manufacturers or university engineers, and country elevator managers have little data to support their estimates. Relationships are complex. Barley loss varies with different cleaning conditions, such as type of dockage, moisture levels, equipment, initial and ending dockage levels, and differing characteristics of barley, such as kernel size and test weight.

Barley loss was varied by the percentage as listed in Table 26 to illustrate sensitivity of cleaning costs to this variable. Barley loss is varied from nil (Table 27) to the base case (Table 25) to a high level or double that of the base case (Table 28). The direct relationship of barley loss to costs (Figure 16) is similar for all three cleaners (A, B, and C). Obviously, costs associated with efforts to reduce barley loss and to increase the dockage price (or screenings) should be evaluated in light of increased costs associated with these efforts. Doubling barley loss from that reported in Table 25 to that in Table 28 nearly doubled cleaning costs because the value of lost barley is such a large share of total costs. Actual impact will be somewhat less, depending on the screenings value.

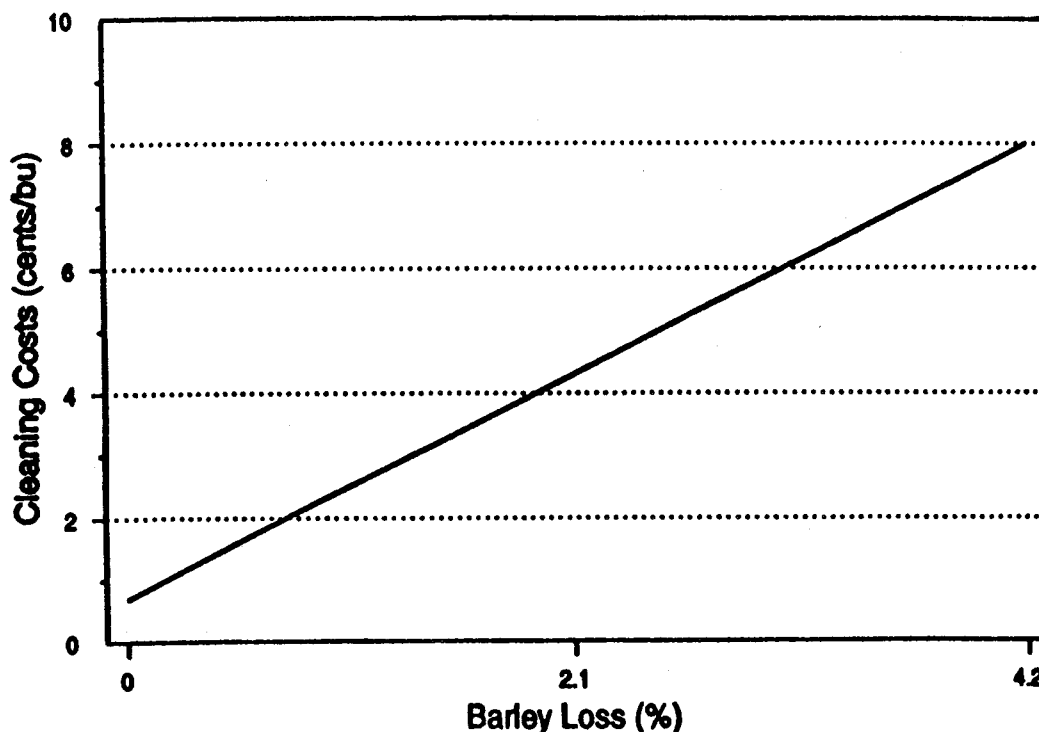


Figure 16. Effects of Barley Loss on Economic-engineering Cleaning Costs for Cleaner B With Beginning and Ending Dockage Levels of 2.5% and 0.8%, Respectively, 1992. See Tables 26, 27, and 28 for assumptions and numerical values.

Impacts of Cleaner Utilization

Grain cleaners have high purchase prices and installation costs compared to variable operating costs. Therefore, use has an important impact on averaged fixed costs. Elevators that closely match their cleaning rate and cleaning capacities have a low total average cleaning cost (Table 29). Costs associated with barley loss are excluded. Use rates of 50, 100, and 150 days per year yielded costs of 1.16¢, 0.66¢, and 0.50¢/bu cleaning, respectively, from an initial dockage of 2.5% down to 0.8%. Doubling use from 50 to 100 days reduced non-grain loss costs an average of 55%. Increasing use by 50% from 100 to 150 days reduced average per bushel cleaning costs, excluding barley loss, by 28%.

Budget Analysis of Cleaning Decisions

Potential benefits from cleaning barley depend on numerous factors as illustrated in Figure 17. Among the most important are the value of screenings and potential savings in shipping costs, both of which vary substantially across locations and through time. The net benefits from cleaning vary directly with the screenings value and with shipping costs. Additional incentives to clean are provided by market discounts for excess dockage and the possibilities for upgrading barley from feed to malting quality. Dockage discounts for barley are not a standard industry practice in the current marketing system, although buyers specify them in individual transactions. Upgrading barley (which typically involves cleaning, sizing, and blending operations) is a more common practice at country elevators, driven by the price spread between feed and malting barley and constrained by qualities of available supplies (levels of plump and thin kernels, protein). An analytical model of upgrading decisions is presented in a companion report (Johnson).

	Sale value of screenings
+	Transportation cost savings
+	Avoidance of market discounts
+	Malting premium through upgrading
-	Costs of cleaning (fixed and variable)
-	Value of barley loss
=	Net benefit from cleaning

Figure 17. Determinants of Net Benefits From Cleaning.

Cleaning costs and the value of barley loss are also critical aspects of the problem. Results from two NDSU surveys (elevators and equipment manufacturers) can be used to support different assumptions about barley loss. Individual manufacturers claim that little or no plump barley is lost in the cleaning process; on the other hand, some respondents to the elevator survey claimed implausibly high levels of

barley loss (i.e., higher than would be consistent with their own estimates of per bushel costs). In view of these inconsistencies, the sensitivity of net benefits to our assumptions concerning barley loss is important.

For sensitivity analysis, the parameter values outlined in Table 30 are used as a "base case." Barley values and screenings are 1991 market-year averages for North Dakota. Freight costs are based on medium-distance shipments (e.g., from Minot to Minneapolis). Cleaning costs are based on estimates presented in the previous section, and barley loss is based on elevator survey results.

TABLE 30. BASE-CASE ASSUMPTIONS FOR SENSITIVITY ANALYSIS

Parameter	Value			
Price of barley ^a (\$/bu)	\$ 1.75			
Value of screenings ^b (\$/ton)	\$18.00			
Freight costs ^c (\$/bu)	\$ 0.50			

	Costs as Function of Cleaning Intensity			
	----- ending dockage -----			
	1.0%	0.8%	0.5%	0.2%
Cost of cleaning ^d (¢/bu)	0.66	0.66	0.75	0.92
Barley loss ^e (%)	1.5	2.1	2.7	4.0

^aAverage price received by North Dakota farmers in 1992.

^bAverage price received by North Dakota elevators, 1992.

^cAssumed freight cost.

^dOperational cost of Cleaner B as described in the Economic-engineering Section.

^eInterpolated from survey data.

Figure 18 shows the impact of initial dockage levels on net benefits from cleaning. Benefits are directly related to the initial dockage level: the greater the initial dockage percentage, the greater the net benefits from cleaning. With an initial dockage level of 4% (dotted line), the net benefit is positive, except when cleaning to low ending dockage levels. When the initial dockage level is 2.5% (dashed line), costs exceed benefits for all ending dockage levels. The decline in benefits at low ending dockage levels (for given initial dockage) is due to higher barley loss associated with intensive cleaning operations.

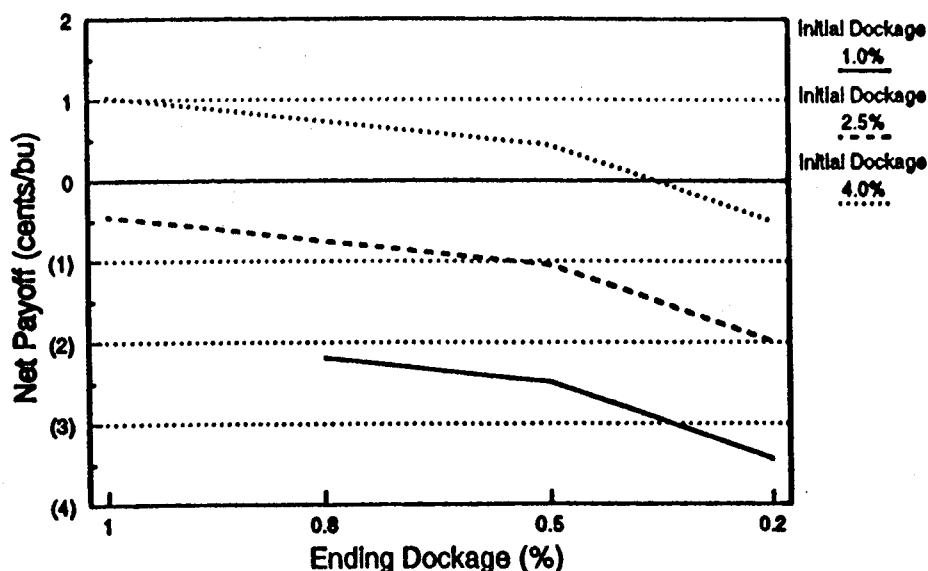


Figure 18. Impact of Initial Dockage Levels.

Assumptions: Barley value is \$1.75/bu, screening value is \$18/ton, and transportation rate is 50 cents/bu. Barley losses are 1.5%, 2.1%, 2.7%, and 4.0% and cleaning costs are 0.66 cents/bu, 0.66 cents/bu, 0.75 cents/bu, and 0.92 cents/bu when cleaning to an ending dockage of 1.0%, 0.8%, 0.5%, and 0.2%, respectively.

The impact of barley loss on net benefits is shown in Figure 19. Assuming barley loss is nil (solid line), net benefits would be positive for all ending dockage levels. Benefits increase slightly at lower ending dockage levels because of greater implied savings on freight costs and greater revenue from sale of screenings. In contrast, base-case assumptions on barley loss (dashed line) indicate negative benefits (i.e., net costs per bushel). Net costs are larger when cleaning more intensively (i.e., to ending dockage of .2%) due to proportionately higher barley loss and lower working capacity associated with intensive cleaning operation.

The value of barley loss reflects the barley price in addition to the quantity of barley kernels removed in the cleaning process. Figure 20 shows that net benefits from cleaning are inversely related to barley price, holding all other parameters constant. At a barley price of \$1.25 per bushel (solid line), the value of barley loss is reduced sufficiently that net benefits from cleaning are positive. Higher barley prices raise the value of barley loss, thereby reducing (or eliminating) the net benefit. Under base-case assumptions (dashed line), the incentive to clean is nonexistent.

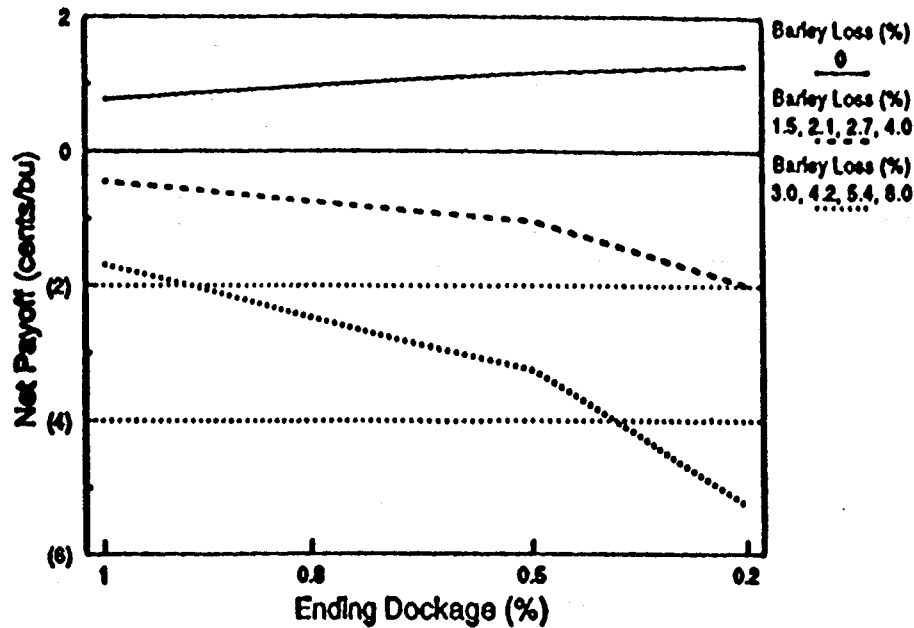


Figure 19. Impact of Barley Loss.

Assumptions: Barley value is \$1.75/bu, screening value is \$18/ton, transportation rate is 50¢/bu, and beginning dockage is 2.5%. Cleaning costs are 0.66 cents/bu, 0.66 cents/bu, 0.75 cents/bu, and 0.92 cents/bu when cleaning to an ending dockage of 1.0%, 0.8%, 0.5%, and 0.2%, respectively.

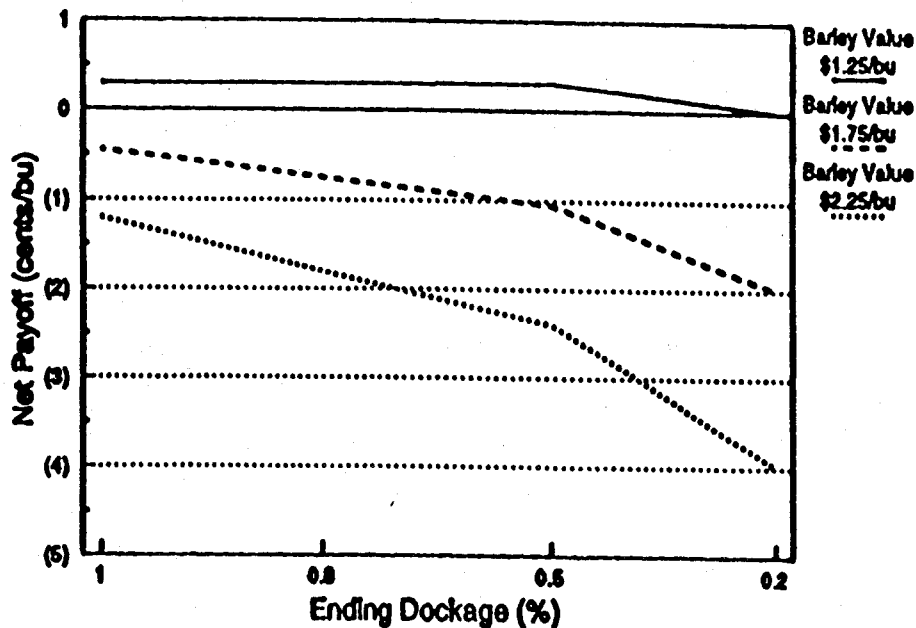


Figure 20. Impact of Different Barley Prices.

Assumptions: Screening value is \$18/ton, transportation rate is 50¢/bu, and beginning dockage is 2.5%. Barley losses are 1.5%, 2.1%, 2.7%, and 4.0%; and cleaning costs are 0.66 cents/bu, 0.66 cents/bu, 0.75 cents/bu, and 0.92 cents/bu when cleaning to an ending dockage of 1.0%, 0.8%, 0.5%, and 0.2%, respectively.

Elevators bear the cost of shipping to buyers.¹⁵ Although elevators are paid for barley on a "dockage deductible" basis, their shipping costs are based on gross weight. Thus, removing dockage before shipment could reduce transportation costs. Figure 21 shows the sensitivity of net benefits to transportation costs. Initial dockage levels are marked along the horizontal axis; we assume that barley is cleaned down to 0.8% ending dockage. Under base-case assumptions (with transportation costs of 50 ¢/bu), the "break-even" point for cleaning occurs at an initial dockage level of 3¼%. At higher transportation rates (typical of longer hauls, e.g., from North Dakota to Portland), cleaning is justified at lower initial dockage levels.

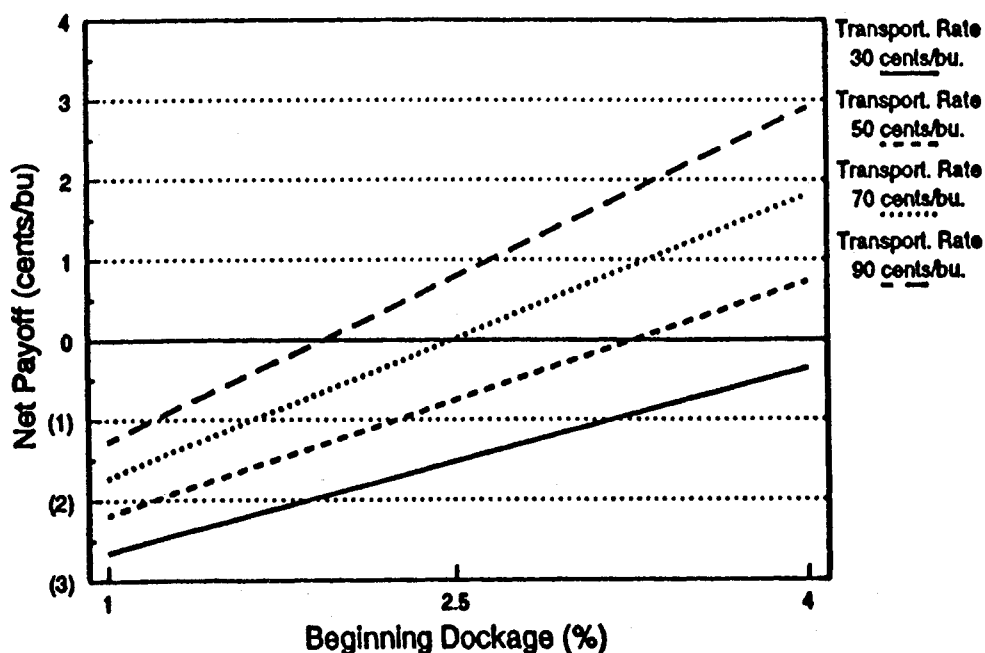


Figure 21. Impact of Transportation Rates.

Assumptions: Barley value is \$1.75/bu, screening value is \$18/ton, ending dockage is 0.8%, barley loss is 2.1%, and cleaning cost is 0.66 cents/bu.

Barley screenings are sold as livestock feed at prices that vary with local market conditions. Figure 22 shows the impact of various screening values on net benefits from cleaning. For reference, the base case assumes screening values of \$18/ton by weight, about one-quarter the value of barley. At higher screening values, cleaning becomes profitable at lower levels of initial dockage. For given

¹⁵In addition, an elevator must elevate some storage space for screenings. Input of screenings to feed markets also may decrease the net price. These costs offset, to some extent, these benefits identified in this analysis.

levels of initial dockage, net benefits increase directly with the screening value.

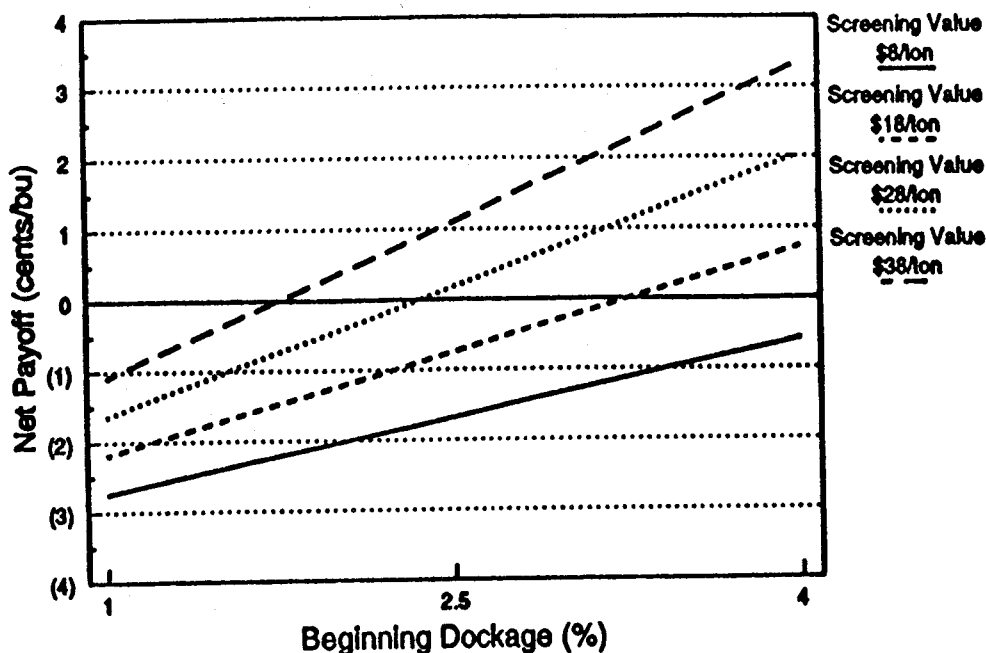


Figure 22. Impact of Screening Values.

Assumptions: Barley value is \$1.75/bu, transportation rate is 50 cents/bu, ending dockage is 0.8%, barley loss is 2.1%, and cleaning cost is 0.66 cents/bu.

Calculating average net benefits is difficult. Cleaning profitability is jointly determined by transportation rates, screenings values, and cleaning costs, which all vary by location and through time. Barley loss, which is critical to evaluating cleaning costs, remains of greatest technical uncertainty.

Impacts of Alternative Policies

Economic incentives determine barley cleaning decisions. This would remain the case if dockage limits were a grade factor for barley. Changes in the grade standards are likely to induce more cleaning only for economic rewards, i.e., intergrade price differentials. In this context, "excess dockage" is not a major concern for domestic feed or malting barley buyers. Malting industry quality requirements determine the most important price differentials in the barley market (between malting and feed barley), which effectively supersede U.S. grade standards.

Estimating aggregate costs and benefits of cleaning on the assumption that a new (hypothetical) dockage limit is applied to all

barley produced and sold illustrates the potential impacts of policy changes. The following analysis incorporates cleaning costs, barley loss, sale of screenings, and transport savings. Data for the 10 major producing states are summarized in Table 31. These states accounted for over 90 percent of domestic barley production in 1991. Cleaning costs are the operational cost of Cleaner B as described in the Economic-engineering Section. Screening values are 1991 regional averages (for Midwest, Pacific, and Mountain states) from the NGFA elevator survey. Transport costs are estimates for typical movements in these corridors. These are highest for Midwest states and lowest for the Pacific states. For simplicity, an initial dockage level of 1.5% is assumed for all producing states.¹⁶ The sensitivity of results to this and other assumptions are examined next.

TABLE 31. BASE-CASE ASSUMPTIONS FOR CALCULATION OF AGGREGATE NET BENEFITS, 10 MAJOR PRODUCING STATES

	1991 Barley Price*	1991 Production	Value of Screenings	Transport Cost
	\$/bu	mil bu	\$/ton	cents/bu
California	2.54	9.4	73	20
Colorado	3.14	10.4	45	35
Idaho	2.77	59.3	45	35
Minnesota	1.79	43.8	33	50
Montana	2.34	85.8	45	50
North Dakota	1.77	138.7	33	50
Oregon	2.25	12.6	73	20
South Dakota	1.74	17.9	33	50
Washington	2.25	37.1	73	20
Wyoming	2.24	10.5	45	35

*1991 marketing year average price received by producers. Wyoming price is based on reported Utah price.

Table 32 shows net benefits (+) or costs (-) by state for various levels of ending dockage. The net benefit of cleaning was derived as described in Figure 17 except for the avoidance of market discounts and malting premium through upgrade. Of all producing states, the net costs are largest in Idaho because of the high barley price in Idaho (Table 31), which implies a higher value for barley lost in the cleaning process. The aggregate net cost for 10 producing states varies with the intensity of cleaning operations. Under base-case assumptions, the aggregate net cost is \$3.9 million when cleaning to

¹⁶This is slightly higher than the national weighted-average dockage level (1.1%) derived from the NGFA survey. For individual states, respondents to the survey were too few to justify use of state averages.

1% ending dockage and \$7.2 million when cleaning to .2% ending dockage.

TABLE 32. AGGREGATE BENEFIT OF CLEANING AT FOLLOWING ENDING DOCKAGE LEVELS (\$)

	Ending Dockage Levels			
	1.0%	0.8%	0.5%	0.2%
California	-52,027	-47,917	-33,595	-65,679
Colorado	-259,908	-336,415	-407,183	-610,760
Idaho	-1,151,886	-1,456,221	-1,727,862	-2,602,669
Minnesota	-328,634	-344,587	-342,530	-527,985
Montana	-856,258	-972,249	-1,027,832	-1,608,510
North Dakota	-1,000,036	-1,033,962	-1,010,800	-1,562,565
Oregon	-14,633	12,777	53,818	58,495
South Dakota	-121,304	-122,463	-116,238	-180,624
Washington	-37,471	45,352	168,254	186,822
Wyoming	-122,581	-143,814	-159,237	-243,526
10 States	-3,944,738	-4,399,497	-4,603,205	-7,157,001

Components of the aggregate cost estimates are shown in Table 33. The value of barley loss is the largest "cost" component; this increases sharply as the ending dockage level is reduced. Revenue from the sale of screenings is the largest "benefit" component under our base-case assumptions.

TABLE 33. COMPONENTS OF AGGREGATE NET BENEFITS UNDER BASE-CASE ASSUMPTIONS

	Ending Dockage			
	1.0%	0.8%	0.5%	0.2%
	\$ million			
Total net benefits	-3.9	-4.4	-4.6	-7.2
Cost components:				
Value of barley loss	-13.7	-19.1	-24.6	-36.5
Costs of cleaning	-2.8	-2.8	-3.2	-3.9
Benefit components:				
Sale of screenings	8.9	12.4	16.4	23.5
Transportation savings	3.7	5.1	6.8	9.7

Table 34 shows the sensitivity of results to the values of individual parameters. A lower initial dockage level (i.e., 1.0%) raises the net cleaning cost, due to reduced screenings revenue and transport savings. Conversely, a higher level of initial dockage

(i.e., 2%) augments these benefits, reducing the net cleaning cost. The value of barley loss (and hence the net cleaning cost) is directly related to the barley price. Higher screening values and transport costs reduce the net cleaning costs.

TABLE 34. SENSITIVITY OF AGGREGATE NET BENEFITS
(\$ MILLION) TO INDIVIDUAL PARAMETERS

	Ending Dockage			
	1.0%	0.8%	0.5%	0.2%
	\$ million			
Base-case assumptions	-3.9	-4.4	-4.6	-7.2
Alternative assumptions				
Initial dockage				
Lower (1%)	na	-7.6	-7.8	-10.4
Higher (2%)	-0.7	-1.2	-1.4	-3.9
Barley price				
10% lower	-2.6	-2.5	-2.1	-3.5
10% higher	-5.3	-6.3	-7.1	-10.8
Screenings value				
20% lower	-5.7	-6.9	-7.9	-11.9
20% higher	-2.2	-1.9	-1.3	-2.5
Transportation cost				
20% lower	-4.7	-5.4	-6.0	-9.1
20% higher	-3.2	-3.4	-3.2	-5.2

Summary and Discussion

Interest in the impact of quality on competition in the world market for most small grains has increased. While much of this debate has centered on wheat,¹⁷ corn, and soybeans, many of the same issues are present in barley. In the U.S. marketing system, dockage in barley is a nongrade-determining factor. Consequently, the dockage level is a contract term, which is subject to negotiation on individual contracts between buyers and sellers. Incentives to remove dockage evolve from the configuration of grade limits in conjunction with intergrade price differentials. However, concern has increased about whether the U.S. system is competitive and whether changes should be legislated with the objective of improving quality of most grains. Specifically, the 1990 Farm Bill enables the Federal Grain Inspection Service (FGIS) to establish or amend grade standards to match levels of "cleanliness" from competing countries.

While these concerns have been stimulated from the competitive environment in wheat and other grains, barley has been included in

¹⁷See Wilson, Scherping, Johnson, and Cobia for a similar study in the case of wheat, as well as the references contained in that study. Other studies are in the process of being released by the USDA Economic Research Service on other grains.

the debate. The purpose of this study was to analyze why and where barley is cleaned, cleaning costs, merchandising practices, and impacts of different policies regulating dockage removal.

Barley is the third leading cereal crop grown in both the United States and the world. Though the United States is a relatively large producer of barley, it is a relatively small exporter of both barley and malt. In the domestic market barley is used primarily for malting purposes and feed. Per capita consumption of malt beverages reached a peak in the early 1980s and has been slowly decreasing. Feed demand competes with corn and is concentrated primarily in the Western states. Although the EC and Canada dominate barley exports, U.S. exports increased in the late 1980s with the assistance of numerous programs. Less than 8% of the total barley exported is of malting quality.

Barley is somewhat unique in the grain industry because its distinct classes and varieties are used throughout the marketing system to indicate quality. Barley is classified by varieties, either feed or malting. In addition, barley is classified as 2-rowed and 6-rowed, depending on the type of variety. The American Malting Barley Association (AMBA) makes recommendations for barley varieties for malting purposes, which are adopted in the grading system.

Canadian grade standards for barley differ from those in the United States in three respects. First, approval for release of varieties is determined through a committee in which the grading agency, the Canada Grain Commission (CGC), participates. Unregistered varieties would be marketed as the lowest grade in their class. Second, export shipments from Canada have a separate grade standard. Third, although dockage is not a grade-determining factor in either country, it must be cleaned in Canada before export (i.e., "commercially cleaned") by regulation.

Specific procedures for measuring and reporting dockage in the two countries differ. In the United States, dockage is certificated in whole percent with the fraction disregarded. Dockage is reported to the nearest 0.1% for Canadian export shipments. Operational procedures also differ. The combined impacts of these applied to specific samples indicate that the CGC always would report a higher dockage level than would the FGIS. On average, if the CGC and FGIS report the same dockage level following their own official testing procedures, Canada's barley would have about 0.45% less dockage than U.S. barley.

Dockage is removed in the U.S. marketing system in response to commercial or implicit incentives. A significant amount of dockage is removed within the domestic marketing system, and this has been increasing. However, dockage in export shipments is substantially greater, varies across importing countries, and has not decreased through time as it has in the domestic marketing system.

Three technologies have been used to remove dockage in the U.S. marketing system: screen cleaners, aspiration, and disk/cylinder.

Although the disk/cylinder has been the most common, screen cleaners are the predominant type being installed. Economic-engineering costs were derived and simulated across various parameters. Important conclusions from this analysis are

1. Barley loss is the most important variable cost associated with cleaning. Barley loss accounts for up to 86% to 89% of the total cost of cleaning. Documented knowledge about any change in the level of barley loss as it is cleaned to lower levels is limited.
2. Cleaning costs were estimated at 4.3¢/bu and 7.9¢/bu, assuming an initial dockage level of 2.5% and ending dockage level of 0.8% and 0.2%, respectively.
3. The value of barley loss and cleaner utilization impacts cleaning costs.

A budget analysis of cleaning decisions was conducted. Results indicate and illustrate impacts of variability in important factors on the net benefit of cleaning or profit from a decision-maker perspective. These factors include initial and ending dockage levels, the value of barley loss and screening, and transport rates. Changes in any of these impact cleaning profitability.

An analysis was conducted to aggregate the costs and benefits of alternative legislated levels of dockage in barley. The analysis included cleaning costs, barley loss, sale of screening and transport savings. Gains or losses in export sales were not included because only a small percentage of exports has been of nonfeed quality. Separate costs and benefits were derived for each of the major barley-producing states.

Under base-case assumptions, the net cost to the industry when cleaning to 1% ending dockage would be \$3.9 million and \$7.2 million when cleaning to 0.2% ending dockage. The net costs are largest in Idaho because of the high barley price, implying a higher value of barley lost in the cleaning process. Sensitivity analysis showed that lower initial dockage levels raised the net cleaning cost, and higher screening values and transport costs reduced net cleaning costs.

References

- American Malting Barley Association, Inc. Issues from 1960 to 1992. *Know Your Barley Varieties*. Milwaukee, WI.
- Ash, M., and L. Hoffman. December 1989. *Barley: Background for 1990 Farm Legislation*. U.S. Department of Agriculture/ Economic Research Service/Commodity Economics Division, Washington, DC.
- Beer Institute. 1992. *Brewers Almanac 1992: The Brewing Industry in the United States*. Washington, DC.
- Briggs, D. E. 1978. Barley. Chapman and Hall LTD., London.
- Canadian Grain Commission. August 1, 1991. *Official Grain Grading Guide*. Office of the Chief Grain Inspector, Inspection Division, Winnipeg, Manitoba.
- Cole, Jim. 1992. Personal communication. Unpublished data, U.S. Department of Agriculture/ERS/Crops Branch, Washington, DC.
- Energy Information Administration. 1992. *Electric Power Monthly*. U.S. Dept. of Energy.
- Fleischmann-Kurth Malting Company. No date. *The Malting Process*. Milwaukee, WI.
- Forbes, Susan M. 1982. In *Grain & Oilseeds: Handling, Marketing, Processing*. Canadian International Grains Institute, Winnipeg, Manitoba.
- Gudmunds, K., and A. Webb. 1989. *PS&D View: Users Manual and Data Base*. ERS, U.S. Department of Agriculture, Washington, DC.
- Hill, Lowell D. 1990. *Grain Grade and Standards*. University of Illinois Press, Urbana, IL.
- Hurburgh, Charles R. 1988. *Cleaning - How and Why*. Proceedings of the 59th International Technical Conference, Grain Elevator and Processing Society, Wichita, KS.
- Johnson, D. Demcey. 1993. "Economics of Barley Sizing and Blending." AE Report (forthcoming).
- Johnson, D. Demcey, and Beena Varghese. 1993. "Estimating Regional Demand for Feed Barley: A Linear Programming Approach." Agricultural Economics Report No. 303, Department of Agricultural Economics, North Dakota State University, Fargo.
- Johnson, D., and W. Wilson. 1993. *North American Barley Trade and Competition*. Agricultural Economics Report, Department of Agricultural Economics, North Dakota State University, Fargo.

- Lovas, R. 1989. *Barley/Malting*. Anheiser Busch, St. Louis, MO, unpublished manuscript.
- Poehlman, John M. 1985. "Adaptation and Distribution." In *Barley*, ed. Donald C. Rasmusson, No. 26 of *Agronomy*, pp. 1-17. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI.
- Quinn, Michael D. 1987. *Facility Operations: Grain Cleaning - Design and Operation Overview*. Proceedings of the 58th International Technical Conference, Grain Elevator and Processing Society, Columbus, OH.
- Scherping, Daniel J., David W. Cobia, D. Demcey Johnson, and William W. Wilson. 1992. *Wheat Cleaning Costs and Grain Merchandising*. Agricultural Economics Report No. 282, Department of Agricultural Economics, North Dakota State University, Fargo.
- Schwartz, P.B., J. Barr, R. Harold, B. D'Appolonia, E. Cummings, M. Kapphahn, and R. Bach. Selected years. *Regional Barley Crop Quality Report*. Department of Cereal Chemistry and Technology, North Dakota State University, Fargo.
- U.S. Department of Agriculture (A), FGIS. October 1, 1990. *Grain Grading Procedure*. Grain Inspection Handbook, Book II. Washington, DC.
- U.S. Department of Agriculture (B), FGIS. March 1, 1992. *Official United States Standards for Grain: United States Standards for Barley*. Washington, DC.
- U.S. Department of Agriculture (D), FGIS/Standards and Procedure Branch. December 1991. *Discussion Paper on the U.S. Standard for Barley*. Washington, DC.
- U.S. Department of Agriculture (E), FGIS. July, 1991. *Inspecting Grain: Practical Procedures for Grain Handlers*. Washington, DC.
- U.S. Department of Agriculture (F), National Agricultural Statistic Service/Agricultural Statistic Board. Various yearly summaries. *Crop Production*. Washington, DC.
- U.S. Department of Agriculture (G), ERS. Various reports. *Feed Situation and Outlook Yearbook*. Washington, DC.
- U.S. Department of Agriculture (H), FGIS. 1993. *Grain Inspection Monitoring Systems (GIMS) Barley Data*. Washington, DC.
- U.S. Department of Agriculture (I), FGIS. 1993. *Export Grain Inspection System (EGIS) Barley Data*. Washington, DC.
- U.S. Department of Commerce, Bureau of the Census. June 1990. *1987 Census of Agriculture*. Volume II, Subject Series, Part 1, *Agricultural Atlas of the United States*, Washington, DC.

U.S. Wheat Associates. *Overview of U.S. Wheat Inspection*. Washington, DC.

Wheat, D., and W. Wilson. 1991. "Tailoring Grains for a Perfect Fit." *Feedstuffs* 63(19).

Wiebe, G. A. 1968. "Introduction of Barley into the New World." In *Barley: Origin, Botany, Culture, Winterhardiness, Genetics, Utilization, Pest*. Agriculture Handbook No. 338, U.S. Department of Agriculture, Washington, DC, pp. 2-8.

Wilson, W., D. Scherping, D. Johnson, and D. Cobia. May 1992. *Impacts of Alternative Policies Regulating Dockage*. Agricultural Economics Report No. 285, Department of Agricultural Economics, North Dakota State University, Fargo.

APPENDIX A

Survey A: NGFA Survey

Survey B: NDSU Survey

SURVEY OF COMMERCIAL ELEVATOR GRAIN CLEANING FACILITIES
PART I: General Questions

1. Name of firm

Address

Telephone ()

2. Check the term that best describes your business operation:

Elevator* (see below)			
Country	Inland terminal	River	Export

3. What is the average annual volume of grain moved through this elevator? (Bu.)

All wheat	Corn	Soybeans	Sorghum	Barley
-----------	------	----------	---------	--------

4. What is this elevator's loadout capacity? (bushels/hour)

Truck	Rail	Barge	Ocean vessel
-------	------	-------	--------------

5. Does this elevator have cleaners? (check one)

Yes	No
-----	----

If Yes, what type of cleaner(s) do you have? (list all units below)

Manufacturer	Model	Year installed	Actual throughput capacity (Bu./hr.)	Type of grain(s) cleaned

6. (a) Can you install or retrofit additional cleaning capacity within the present available space? (check one) . . .

Yes	No
-----	----

(b) If Yes, how much additional capacity can be installed or added?

bu./hr.

(c) Estimate how much the additional capacity would cost you (check one)

Less than \$100,000	\$100,000 to \$500,000	Over \$500,000
---------------------	------------------------	----------------

Please complete the following commodity-specific questionnaires for winter wheat, spring wheat, corn, soybeans, sorghum, and barley for each commodity that accounts for at least 10 percent of your entire operation.

* Country elevator is defined as one which receives over 50 percent of its grain from farmers, while inland terminal receives over 50 percent of its grain from other elevators.

PART II: Barley-Specific --1

1. Barley handled by class (percent) . . .

Malting	%	Feed	%
---------	---	------	---

2. Percent of barley received annually from:

Farmers	%	Other elevators	%
---------	---	-----------------	---

3. Estimate the average factor percentages of inbound barley:

Dockage	%	Foreign material	%	Thins	%
---------	---	------------------	---	-------	---

4. What are the primary sources of discounts in barley you receive? (rank responses: 1- Great importance, 2- Some importance, 3- Little importance)

	Rank		Rank
Other grains		Weed seed	
Thin barley		Other (specify)	

Malting barley (answer #5, 6, 7, 8, and 9 only if you handle malt barley)

5. Do buyers routinely purchase on gross weight basis _____ or a weight deduction (net of dockage) _____? If weight deduction, beginning at what percent? _____%

6. Besides the weight deduction, list discounts (in cents/bu.) routinely charged for the following levels of dockage: (or attach a recent discount schedule)

0.5%	1.0%	1.5%	2.0%	2.5%	Over 3.0%
------	------	------	------	------	-----------

7. What premiums (in cents/bushel) do buyers of your base grade of malting barley routinely offer for the following levels of dockage?

0.5%	1.0%	1.5%	Over 1.5%
------	------	------	-----------

8. What discounts (-) or premiums (+) (in cents/bushel) do buyers of your base grade of malting barley routinely charge or offer for the following levels of foreign material?

0.5%	1.0%	1.5%	2.0%	2.5%	Over 3.0%
------	------	------	------	------	-----------

9. What discounts (-) or premiums (+) (in cents/bushel) do buyers of your base grade of malting barley routinely charge for the following levels of thin barley?

5.0%	6.0%	8.0%	10.0%	12.0%	14.0%	Over 15.0%
------	------	------	-------	-------	-------	------------

Feed barley

10. Do buyers routinely purchase on gross weight basis _____ or a weight deduction (net of dockage) _____? If weight deduction, beginning at what percent? _____%

11. Besides the weight deduction, list the discounts (in cents/bu.) buyers routinely charge for the following levels of dockage: (or attach a recent discount schedule)

0.5%	1.0%	1.5%	2.0%	2.5%	Over 3.0%
------	------	------	------	------	-----------

PART II: Barley-Specific --2

12. What premiums (in cents/bushel) do buyers of your feed barley routinely offer for the following levels of dockage?

0.5%	1.0%	1.5%	Over 1.5%
------	------	------	-----------

13. What discounts (-) or premiums (+) (in cents/bushel) do buyers of your base grade of feed barley routinely offer for the following levels of foreign material?

0.5%	1.0%	1.5%	2.0%	2.5%	Over 3.0%
------	------	------	------	------	-----------

14. What percent of stored barley is treated with these protectants:
Malathion _____% or Reldan _____% or others (specify) _____%

15. How often is stored grain is fumigated? _____ times/year
If applicable, estimate the cost per fumigation: _____ cents/bushel

16. Do you have aeration equipment in your grain bins? Yes _____ No _____
How often is stored grain turned for conditioning? _____ times/year

17. Do you clean barley that you handle
(excluding cleaning for seed)?
(If Yes, skip to #19)

Yes	No
-----	----

18. If No for #17, what are the major reasons for not cleaning?	Rank (1= Great importance, 2= Some, 3= Little)
Insufficient market for cleanings	
Insufficient premium for clean grain	
Equipment investment too costly	
Difficulty in handling screenings	
Inadequate storage for screenings	
Time constraints	
Other (specify)	

Answer the remaining questions only if you clean barley (excluding cleaning for seed) in most recent years.

19. What reasons do you clean barley?	Rank (1= Great importance, 2= Some, 3= Little)
To avoid discount	
Increase storability	
Reduce moisture problems	
Reduce insect problems	
Increase dryer or aeration efficiency	
Maintain or increase export share	
Meet contract specification	
Other (specify)	

20. What is the average percentage of barley cleaned annually? _____ %

21. How much dockage is usually removed from barley? _____ percentage points

PART II: Barley-Specific --3

22. (a) Estimate the cost to clean out the dockage in #21 (includes energy, wages, and interest on working capital but excludes grain lost) _____ cents/bushel

(b) Estimate what it would cost (in cents/bu.) to reduce dockage by the following:

0.0-0.5%	0.5-1.0%	1.0-1.5%	1.5-2.0%	Over 2%
¢/bu.	¢/bu.	¢/bu.	¢/bu.	¢/bu.

23. When is your barley usually cleaned? (Percent)

at receiving	%	during storage or turning	%	At loadout	%
--------------	---	---------------------------	---	------------	---

24. How much barley screenings were produced in 1990? _____ tons (2,000 lbs.)

25. How were your 1990 barley screenings used?	Percent	Estimated sales value or disposal cost (\$/ton)
Sold to feed market	%	\$
Used in your own feed mill	%	\$
Disposed as waste	%	\$
Other (specify)	%	\$

26. Estimate the average distance that screenings sold were hauled: _____ miles.

27. What is the storage capacity available for screenings? _____ tons

28. Describe any regulatory or legal restrictions on disposing screenings: _____

29. (a) Is there equipment to pellet screenings at this elevator? Yes ____ No ____

(b) If Yes, what percent of screenings were pelleted? _____%

30. Please fill in the following monthly price and sales information for 1990. If you know the screenings price (even if none were sold that month) please report it.

Month	Price (\$/ton)	Percent of 1990 sales
January	\$	%
February	\$	%
March	\$	%
April	\$	%
May	\$	%
June	\$	%
July	\$	%
August	\$	%
September	\$	%
October	\$	%
November	\$	%
December	\$	%
1990		100%

**Survey of Country Elevator Managers on the Capabilities
to Remove Dockage from Barley
January 1992**

1. Name of firm _____
2. Location of firm _____
3. What is the largest number of rail cars that your elevator can load in one day?
 _____ (a) Less than 6 cars
 _____ (b) Between 7 and 26 cars
 _____ (c) Between 27 and 54 cars
 _____ (d) More than 54 cars
4. What is the total plant storage capacity at this facility? _____ bushels
5. Do you have a separate elevator (house) for handling barley?
 Yes _____ No _____
6. Average volume of barley handled annually:
 a) 2-row _____ bu., 6-row _____ bu.
 b) Average percentage of above amounts that is of malting varieties:
 2-row _____ %, 6-row _____ %
 c) Average percentage of each type that is sold as malting barley:
 2-row _____ %, 6-row _____ %
7. What percentage of the barley that you clean is sold as:
 malting _____ % feed _____ %
8. Of the barley shipped, what percent is:
 Cleaned to remove dockage _____ % graded (sized) _____ %
9. a) Provide the following information about the one cleaner you use most to remove dockage from barley.

Manuf.	Purchased	Rated	Technology (check one)
Year	Est. Price	Est. Install. Cost	Cap. (bu/hr)
			<div style="display: flex; justify-content: space-between;"> <div style="text-align: center;"> Disk/ Cylinder </div> <div style="text-align: center;"> Screen Gravity </div> <div style="text-align: center;"> Rotary </div> <div style="text-align: center;"> Flat </div> <div style="text-align: center;"> Other </div> </div>

- b) What percentage of the barley you cleaned is processed through this cleaner?
 _____ %

- c) What is the working capacity (bu/hr) of this machine when cleaning to each of the following dockage levels:
 1.0% _____ bu/hr 0.5% _____ bu/hr 0.1% _____ bu/hr
- d) Estimate your current operating costs (including loss of plump barley) in cents/bu, when cleaning to each of the following dockage levels:
 1.0% _____ ¢/bu 0.5% _____ ¢/bu 0.1% _____ ¢/bu
- e) Estimate percentage of plump barley loss associated when cleaning to each of the following dockage levels:
 1.0% _____ % 0.5% _____ % 0.1% _____ %
- f) Percentage of the operating costs to remove dockage from barley allocated to: (total=100%)
 Repairs _____ % Labor _____ % Energy _____ %
 Additional Elevation _____ % Loss of plump barley _____ %
 Other _____ % (please describe)

10. a) Provide the following information about the one grader (sizer) you use most to remove thins from barley.

<u>Manuf.</u>	<u>Purchased</u>		<u>Rated</u> <u>Cap.</u> <u>(bu/hr)</u>	<u>Technology (check one)</u>				
	<u>Est.</u> <u>Cleaner</u> <u>Year</u>	<u>Est.</u> <u>Install.</u> <u>Price</u>		<u>Disk/</u> <u>Cylinder</u>	<u>Screen</u> <u>Gravity</u>	<u>Rotary</u>	<u>Flat</u>	<u>Other</u>

- b) What percentage of the barley you grade is processed through this cleaner?
 _____ %
- c) What is the working capacity (bu/hr) of this machine when grading (sizing) to each of the following level of thins:
 10.0% _____ bu/hr 7.0% _____ bu/hr 5.0% _____ bu/hr
- d) Please estimate your current operating costs in cents/bu, when grading (sizing) to each of the following level of thins:
 10.0% _____ ¢/bu 7.0% _____ ¢/bu 5.0% _____ ¢/bu
- e) Percentage of the operating costs to remove thins from barley allocated to: (total=100%)
 Repairs _____ % Labor _____ % Energy _____ %
 Additional Elevation _____ % Other _____ % (please describe)

11. What percentage of the barley that you clean is elevated specifically to run through the cleaner?
 _____ % Cost of elevation (¢/bu) _____
12. What percentage of the barley that you clean is cleaned at the time of:
 Delivery by farmer _____ % Shipping to customer _____ %
 Turning _____ % As time permits _____ %
13. What percentage of the total barley you receive is binned according to dockage levels? (check one)
 0-5% _____ % 6-25% _____ % 26-50% _____ % 51-100% _____ %
14. When shipping barley, what percentage of barley is blended to specifically meet desired dockage levels?
 0-5% _____ % 6-25% _____ % 26-50% _____ % 51-100% _____ %
15. At what dockage level percentage do you not clean barley sold as malting barley?
 harvest _____ % postharvest _____ %
16. To what dockage level percentage do you clean barley sold as malting barley?
 harvest _____ % postharvest _____ %
17. At what percentage of thins (on average) do you not clean barley sold as malting barley?
 harvest _____ % postharvest _____ %
18. To what percentage of thins (on average) do you clean barley sold as malting barley?
 harvest _____ % postharvest _____ %
19. What average price did you receive for barley screenings for the past 3 years?
 1989 _____ \$/ton 1990 _____ \$/ton 1991 _____ \$/ton
20. What percentage of screenings sold are thins: _____ %
21. a) Please rank (1-7, 1=most important) the following factors according to their relative importance in your decision to clean barley.
- | | |
|-----------------------------------|---|
| _____ Initial dockage levels | _____ Transportation savings |
| _____ Meet contract specification | _____ Storage savings or improved storability |
| _____ Removal of thins | _____ Upgrading feed quality to malting quality |
| _____ Price of screenings | |

- b) Please rank (1-6, 1-most important) the following factors according to their relative importance in your decision to not clean barley.

<input type="checkbox"/> Time constraints	<input type="checkbox"/> Contracts don't require cleaning
<input type="checkbox"/> Insufficient premiums & discounts	<input type="checkbox"/> Lack of equipment
<input type="checkbox"/> Difficulty in cleaning barley	<input type="checkbox"/> Cost of cleaning

22. Which of the following statements would best describe the change you would need to make if all barley was to be shipped at the 0.5% dockage level? (check only one)

(check one)

Required Changes

- ☐ No equipment or operational changes would be necessary
- ☐ No equipment changes but would require additional elevation or handling
- ☐ Installation of additional cleaning equipment without major modifications to your facility
- ☐ Installation of additional cleaning equipment with major modifications to your facility

23. Would you provide a discount or premium schedule to provide incentives for delivery of low dockage barley if all barley had to be shipped at the 0.5% dockage level?

Yes ☐ No ☐

Buyers of Your Barley

24. a) Do buyers routinely purchase on gross weight basis ☐ or a weight deduction (net of dockage) ☐ ?
If weight deduction, beginning at what percent? ☐ %
- b) Besides the weight deduction, list discounts (in cents/bu.) routinely charged for the following levels of dockage:
- 0.5% ☐ ¢/bu 1.0% ☐ ¢/bu 2.0% ☐ ¢/bu Over 3.0% ☐ ¢/bu
- c) What discounts (-) or premiums (+) (in cents/bu) do buyers of your base grade of malting barley routinely charge for the following levels of thin barley?
- 5.0% ☐ ¢/bu 7.0% ☐ ¢/bu 10.0% ☐ ¢/bu Over 15.0% ☐ ¢/bu

APPENDIX B

Economic-engineering Costs Under Alternative Depreciation Assumptions

TABLE B1. ESTIMATED BARLEY-CLEANING COSTS (DEPRECIATION BASED ON USE) FOR A COUNTRY ELEVATOR, CLEANER B (SCREEN), 2,200 BU/HR, INITIAL DOCKAGE LEVEL OF 2.5%, CLEANING FOR 700 HOURS PER YEAR, 1992

Cost Component	Cleaned to Dockage Level:			
	0.8%		0.2%	
	Annual	¢/bu	Annual	¢/bu
Bushels cleaned	1,386,000		1,001,000	
Fixed costs:				
Depreciation	\$ 898	0.06	\$ 1,243	0.12
Opportunity	3,144	0.23	3,144	0.31
TOTAL FIXED COSTS	4,042	0.29	4,389	0.43
Variable costs:				
Barley loss ^a	\$50,936	3.67	\$70,070	7.00
Energy	1,006	0.07	1,006	0.10
Labor	1,079	0.08	1,079	0.11
Maintenance	328	0.02	328	0.03
TOTAL VARIABLE COSTS	53,349	3.84	72,483	7.24
TOTAL COSTS	\$57,391	4.13	\$76,870	7.67

^aAssuming 2.1% and 4.0% barley loss when cleaning to 0.8% and 0.2%, respectively.

TABLE B2. BARLEY-CLEANING COSTS
(DEPRECIATION BASED ON USE) WITH A
USE RATE OF 700 HOURS PER YEAR, 1992

<u>Cleaning</u>		Assumed Barley Loss	<u>Type of Cleaner^a</u>		
From	To		A (1.5)	B (2.2)	C (7.2)
----- percent -----			----- ¢/bu -----		
4.0	1.0	1.5	3.1	3.1	3.1
	0.8	2.1	4.2	4.2	4.4
	0.5	2.7	5.3	5.3	5.6
	0.2	4.0	7.8	7.9	8.2
2.5	1.0	1.5	3.1	3.1	2.9
	0.8	2.1	4.1	4.1	4.2
	0.5	2.7	5.3	5.3	5.3
	0.2	4.0	7.7	7.7	7.7
1.0	0.8	2.1	4.1	4.1	4.0
	0.5	2.7	5.2	5.2	5.1
	0.2	4.0	7.6	7.5	7.5

^aRated capacity (1,000 bu/hr) in brackets.

APPENDIX C

Survey of Grain Cleaner Manufacturers

**Survey of Grain Cleaner Manufactures on Removing Dockage from Barley
July 1992**

Please complete a form for cleaners most commonly used for barley at the farm, country elevator, export elevator, and processing plants. Please enclose brochures on this cleaner if available.

1. Model: _____ Price: _____
 Typical installation costs (excluding remodeling): _____
 Rated Capacity (bu/hr): Market _____ Seed Cleaning _____

2. This model uses the following technology(ies) to remove dockage.
 Please specify by checking all that apply:

Aspiration _____	Air-screen _____	Screen _____
Cylinder/Disk _____		
Other (describe) _____	Screen (gravity) _____	
	Screen (gyrating) _____	
	Screen (reciprocating) _____	
	Screen (rotating) _____	

3. For the cleaning system described in Question #2 please estimate the following:
 - a. Expected useful life (bushels):
 Cleaner: _____ Screens or Cylinders/Disks: _____

 - b. Horse power requirements: _____

 - c. Labor requirements (per 8 hour of operation): _____

 - d. Maintenance and repair costs (per 8 hours of operation): _____

 - e. Cost of replacement cylinders/disks or screens:
 Screens (unframed): _____ Screens (framed): _____
 Cylinders/Disks: _____

 - f. Labor (hours) required to change screens or cylinder/disks.
 Screens (unframed): _____ Screens (framed): _____
 Cylinder/Disks: _____

4. Does the cleaning system described in Question #2 have a dust collection system: Yes: _____ No: _____

5. If the cleaning system described in Question #2 needs an additional dust collection system, please provide the following for the additional dust system:

- a. Cost of this dust system (excluding installation) _____
- b. Daily maintenance and repair costs (per 8 hour of operation): _____
- c. Does this dust system have a power source independent of the cleaning system: Yes: _____ No: _____

IF Yes, what airflow rate (cfm) is required for the dust collection system:

cfm: _____

Answers to question #6 and #7 probably vary with many factors. Please make estimates that are most typical.

6. Assuming that removing various levels of dockage changes throughput, please provide the percent of rated market cleaning capacity when cleaning from a given initial dockage level to the desired ending dockage level. If removing a particular amount is not possible, please indicate with a zero (0).

Initial Dockage	Ending Dockage Level			
	1.0%	0.8%	0.5%	0.2%
4.0%				
2.5%				
1.0%	X			

7. With properly sized screens or cylinders/disks in place, what percent of malting quality barley is removed with the dockage when cleaning to the following dockage levels:

1.0% _____ 0.8% _____ 0.5% _____ 0.2% _____

8. Please provide names of two or more firms that are currently using this cleaner to clean barley. We wish to obtain information for this cleaner in field conditions.

 Contact Person Firm Address Phone #